

Very Poor Quality

NIST GCR 01-807

THE NIST REPORT FOR THE MSU EPICENTER

Kath Williams
Bob Berkebile
Jason McLennan
Kathy Achelpohl
Phaedra Svec



NIST

National Institute of
Standards and Technology
Technology Administration
U.S. Department of Commerce

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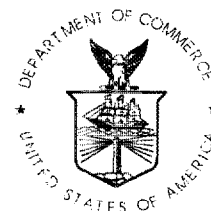
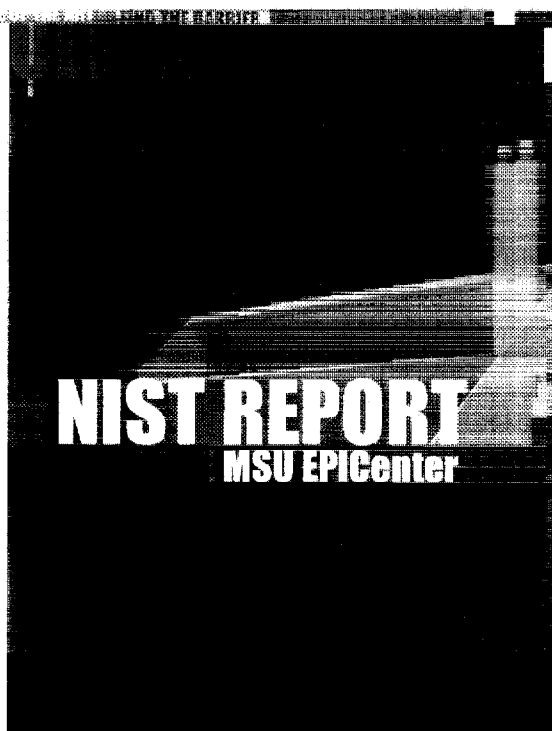
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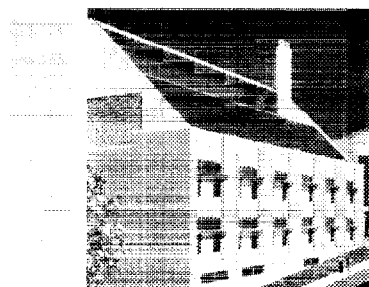
September 2000



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PREFACE

Bob Berkebile FAIA



It was the summer of 1994, a summer ripe with possibilities, yet conflicting forces were at work. The American way of life was seemingly alive and well, increasingly visible and attractive to the developing world. We Americans (approximately three percent of the earth's population) were holding steadfastly to a way of life that was setting records for consumption, waste, and pollution. A growing body of scientists and environmentalists were forecasting dire consequences as the developing world rushed to imitate the American model.

But important shifts were underway. A five-year partnership between the American Institute of Architects Committee on the Environment, the US EPA, and corporate America had been publishing the results of their joint research in the Environmental Resource Guide. Paul Hawken's new book, *The Ecology of Commerce*, was finding its way into the boardrooms of corporate America. The design, manufacturing and construction industries were beginning to take notice.

New, more sustainable approaches and tools were tested in a series of national demonstration projects that began with the Greening of the White House. Early results had been encouraging enough that the concept spread to include countless public-private partnerships, guidelines, standards, tools and publications. Scores of demonstration projects were born out of the success of the Greening of the White House. These projects included the Greening of the Pentagon, Grand Canyon, Yellowstone, Antarctica, the relocation of communities out of the Mississippi River flood plain, and four projects sponsored by the National Institute of Standards and Technology (NIST). The seeds of change had been planted.

Our firm, BNIM Architects, had been engaged by Montana State University to help design a concept for one of the NIST demonstration projects. The goal was to create a concept for a building that would be more energy-efficient than any building of its type. Jay Tomlinson and I made a trip to Bozeman, Montana to gain a better understanding of our new client, their goals, and the place we had been given as the site for this new benchmark facility. After visiting with local historians and ecologists we borrowed a copy of the Lewis and Clark journal from our new friend and local associate, Don McLaughlin, and the journey began.

We knew that retracing the steps of Lewis and Clark and reading their journal would contribute to a greater understanding of this place. It did and more! I knew from my own experience that today, Meriwether Lewis would be hard pressed to recognize anything he had described at the confluence of the Missouri and Kansas Rivers during his four-day visit in May of 1804. The city that later grew up on the spot he described was my home. Lewis would no longer find the Kansa Indians, bison, or the Carolina Parakeet that once were so common in this area (this year the Carolina Parakeet joined the growing list of extinct species). He would surely be even more startled by the absence of high limestone bluffs and the "broad Missouri River," which were replaced by Kansas City's central business district and by the Corps of Engineers' managed river channel.

NEW YORK
AND
SAN FRANCISCO
AND
LOS ANGELES
AND
CHICAGO
AND
PHILADELPHIA
AND
WASHINGTON, D.C.



Preface
Bob Berkebile

THE SKY

I assumed things would be more to Meriwether's liking under the "big sky" of Montana and in the Gallatin Valley where "a river runs through it," but it became painfully obvious that human development had changed the landscape even in Montana. The rich tapestry of flora and fauna that Lewis and Clark had described were now hard to find. Nor did we see foliage too dense to walk through or beaver dams too numerous to count. They had been replaced by the monoculture of agribusiness with its attendant fences and irrigation canals.

We were so moved by this experience that it changed our approach. We lobbied MSU's project manager, Peter Perna, and Jim Hill at NIST to enlarge the scope of our work beyond energy efficiency to resource efficiency and strategies for restoring biodiversity. The proposal was accepted, the NIST grant was doubled, and the team of experts enlarged.

It was this additional grant that helped us discover that it might be possible to accelerate the rate of change in the design and construction industry. I recalled a concept Buckminster Fuller taught us in school: "The only way to make significant change is to make the thing you're trying to change obsolete." The project team agreed with Bucky and during the first design charrette ten goals were embraced that held the potential to change the industry.

As passages were read from the Lewis and Clark journal at team meetings and design charrettes, there was a growing realization about the similarities between our journey of discovery and the one that had occurred almost 200 years before. Only gradually did we realize that many of our most important breakthroughs with new systems, technologies and materials were resulting from intuition and collaboration. The design concept that evolved and the potential it represented exceeded expectations and triggered remarkable responses from participants, sponsors and stakeholders.

NIST and Congress provided an additional \$1.2 million to advance this concept through more detailed design, including prototyping and testing of materials and technologies. The MSU students, led by student body president Jim McCray, voted to increase their fees to help fund the design and construction of this new facility with the stipulation that it be moved from the Technology Park to the MSU campus. Joseph Campbell's "invisible helping hands" came to mind.

The design team was moved by these actions and decided to raise the bar for programming and design of the green building on campus. We had discovered during the resource mapping exercise and the development of new building materials from the Montana waste stream that it was no longer reasonable to accept the theory that trade-offs are necessary between the environment and the economy. A single design decision could and should add economic, social and environmental vitality to the region. The decision was made to extend this approach to all decisions for the new project. It had also become obvious that understanding the barriers to change was critical in creating new state of the art. With the lessons learned up to that time and the unprecedented levels of support this project enjoyed, the decision was made to reach for new state of the art in each aspect of the MSU green building. The term "Plus Ultra" (Latin for "more, beyond") gave us a name for our new methodology.

Kath Williams joined the team as MSU project chief just as the project was getting its legs and moving to the MSU campus. As the project was renamed the EPICenter (Educational Performance and Innovation Center) and grew to 250,000 square feet, Kath quickly assumed a role similar to that of Sacagawea and guided the team through fertile landscapes of new users, new partners and additional funding. She also reassured us that the team was still on course during the storms that resulted from changing sites, budgets, building programs and political challenges - not to mention multiple presidents, vice presidents, CFO's, provosts and department heads.

Today, seven years since we began our journey with Montana State University, two phases of the project are complete—the Center for Computational Biology and new teaching laboratories for chemistry—both in renovated space. Contract documents have just been completed for the Pilot building, a 30,000 square foot addition to Gaines Hall. The Pilot building will contain the Center for the Development of Bioactive Compounds, organic chemistry teaching labs and informal student spaces, and many Plus Ultra materials, systems and technologies developed for this project.



At the time of this writing I have just returned from a hike in the Montana Spanish Peaks with Kath Williams, Jim Hill, and Rick Johnson (of Fisher Hamilton, one of our industry partners). It was beautiful! But I was struck by the environmental degradation since our Lewis and Clark trip seven years earlier. Sprawl has accelerated from Bozeman toward the mountains. The natural profile of the foothills has been broken with what the local residents refer to as “starter castles and ranchettes” built by “cappuccino cowboys” (because they drive to town in their new SUV’s for cappuccino). The record drought has triggered record forest fires still smoldering nearby. Are these events related? I think so.

Following the hike we were joined by additional team members and presented working prototypes of a diverse collection of new Plus Ultra systems, technologies, tools, and materials to Jim Hill. The alpha tests have been impressive and beta prototypes have just been installed in the Safety and Risk Management Facility for a year of testing. All those assembled are enthusiastic. They believe the prototypes will continue to test well and be quickly integrated into standard practice, dramatically increasing resource efficiency and reducing pollution. Chemistry professor John Amend presented the new prototype chemistry teaching labs and the computer software his team developed. Already reaching universities all over the country, they believe it will change how we teach and do research. Civil engineering professor Otto Stein and his students gave a tour of the constructed wetlands in the Plant Sciences Greenhouse. They shared the remarkable discoveries made in advancing the capacity and durability of biological wastewater treatment systems for the Pilot building test cells. The presentations were convincing.

Will all these impressive successes create the level of change we had hoped to accomplish, including our goal of restoring some of the beauty and vitality that Lewis and Clark witnessed? It is not clear. There is good cause to celebrate the breakthroughs presented to Jim Hill and delineated in this report. But my hope for the future lies in the stories of personal and corporate transformation shared by Kath, Rick and others. We are more capable and passionate as a result of this journey of discovery.

Of one thing I am certain. My life has been enriched by this party of explorers once described by Amory Lovins as “the rocket scientists of sustainable design.” I am honored to have traveled with them.

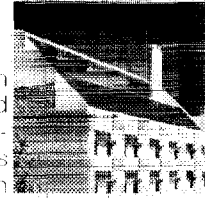
R.J.B.
Bozeman, Montana. September 2000



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ACKNOWLEDGMENTS

Thank You



This is one of those times in life when words do not suffice. Saying "thank you" is not enough to show appreciation to a large number of people. So many individuals have contributed beyond their contracts and grants to create the systems, technologies and materials documented in this report. Through an amazing collaborative effort, among diverse individuals from California to England, exemplary work was produced. Included in the appendix is an honor roll that attempts to list all of the individuals that have helped to shape the direction and quality of this body of work. Due to the evolution of the team over seven years, some individuals may have been erroneously overlooked. We would like to apologize in advance for any oversights.

Special recognition must be given to certain groups and individuals.

First of all we wish to thank Senator Conrad Burns, NIST in general and Dr. Jim Hill in particular for making this project a possibility and having the vision to trust this team of pioneers with efforts to "stretch the envelope."

Secondly, many thanks to Montana State University for "hosting" the project with special thanks to the students, faculty and staff who supported it.

And thirdly, to the diverse team of scientists, engineers, architects, and corporations who made contributions that will extend beyond these pages and into the future of building and construction.

Every successful project has an essential group of team players who are the core. They often go unnoticed and are certainly not thanked enough. The NIST research and development project could not be what it is without the dedication, creativity, and leadership of BNIM Architects of Kansas City. Chris Kelsey's intelligence and clarity galvanized the team; Kathy Achelpohl inspired us with her wisdom and humor; Bryan Gross led us through a great Pilot building design; Andy VanBlarcum consistently converted vague ideas to working solutions, and Jason McLennan brought technical expertise, eloquence with the written word, and youthful exuberance that was contagious.

The EPICenter project team was blessed by having Phaedra Svec of BNIM, and Audrey Thuriow and Nancy Harris in Bozeman to provide answers when there were seemingly none, and communication and clarity to keep the project team productive. Thank you all for keeping us on the path to success.

The quality of the NIST Final Report is due to the efforts of all contributors. We would like to recognize the editors and designers of the book including John Gasaway, Zack Shubkagel, Beena Ramaswami, Kristin Gossman and Stefania Vigarani of BNIM, and John Lewis of the EPICenter project office. Thank you!

And finally, a special thank you to the families of all those whose passion resulted in so much time away from home working to create the kind of change that makes this project groundbreaking and unique.

The result of your brilliance is awesome. Thank you!

Kath Williams, Montana State University
Bob Berkebile, BNIM Architects

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Kath Williams Ed.D + Bob Berkebile FAIA

INTRODUCTION



"Never doubt that a small group of thoughtful committed citizens can change the world. Indeed it's the only thing that ever has."

Margaret Mead

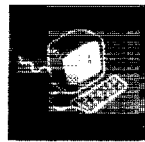
The success of natural systems depends upon diversity, efficiency and interdependence. The complexity of natural systems, as well as the complexities of our communities, can be better understood by starting with basic underlying principles and values. Montana State University and all the players, through the "Green Building" project, have learned that collaboration, diversity and participation are key ingredients in creating a process that can lead to the discovery of new solutions.

Early in the process, the original MSU visionaries had individual as well as institutional goals in mind when they applied for the first \$200,000 planning grant from the National Institute of Standards and Technology (NIST). Vice President of Research, Creativity, and Technology transfer, Robert Swenson, saw what he called "insurmountable opportunities" from a green building project. Peter Perna, Director of the Center for Economic Recovery and Technology transfer (now MSU/NASA TechLink), became project director for what he saw to be an incubator for new companies interested in "green" technologies. And Professor of Architecture Jerry Bancroft wanted to bring cutting-edge architectural and sustainable design expertise to MSU classrooms so that students and faculty could benefit.

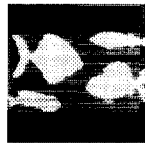
Together, these three searched the nation for an architectural firm that could lead a design team for what would be "the most energy-efficient building on the planet." Bob Berkebile of BNIM Architects, Kansas City, Missouri, was selected and the four set about to develop an appropriate team, one that could "change the way we design, build, operate and maintain buildings in the 21st century." The team envisioned a national demonstration project that would bring educational and technology transfer opportunities to MSU and the Gallatin Valley.

As the original design team stood in that valley, they did not see "The Valley of the Flowers" that Meriwether Lewis and William Clark described in 1805. What they did see was an opportunity to restore the site and build upon it a structure that would be in harmony with nature. During the first charrette in 1994, a diverse group of international, national, and local experts assembled to develop and embrace the following goals:

DESIGN GOALS



Increase efficiency in flows of information and materials.



Restore biodiversity at the site and neighborhood.



Improve economic vitality of the community and region.



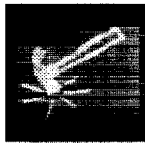
Promote human health, well-being and productivity.



Set new standards for energy efficiency and resource conservation (operating energy has priority over embodied energy).



Reduce global warming, ozone degradation, and acid rain by increasing efficiency, restoring biodiversity and reducing the release of contaminants.



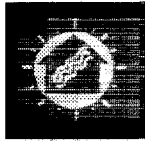
Improve tools for designing, constructing, operating and evaluating building systems.



Explore the potential of human resources through education and empowerment as a major factor in environmental performance, human health and economic productivity.

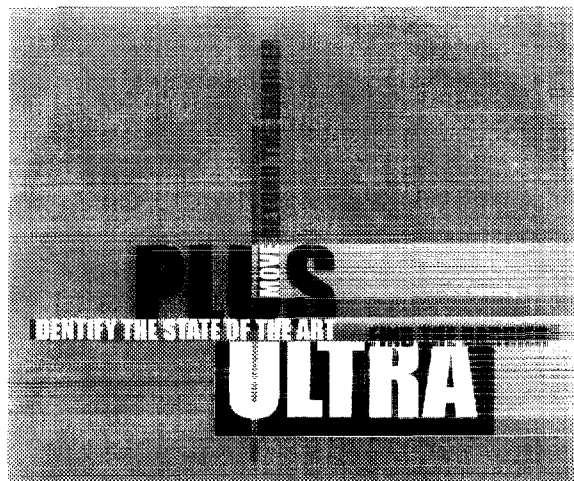


Express "Firmness, commodity and delight" (Vitruvius) in the spirit of this region so that the user/visitor can "Feel it through their skin." (Deborah Butterfield).



Maximize the pedagogical opportunities of the process and facility.

LEWIS AND CLARK



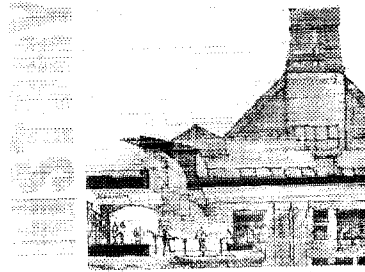
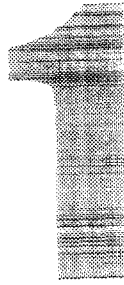
Reading the journal of Lewis and Clark became a tradition at EPICenter design charrettes throughout the first five years. The parallels were often striking and the warnings profound. Project chief Kath Williams often evoked these similarities as metaphors for the journey of discovery undertaken by the project teams.

A second theme, "Plus Ultra," was adopted as a guiding strategy and principle of the project. Plus Ultra, Latin for "more, beyond" became a philosophy for the design process and gave the project team a system for organizing their thoughts.

One of the central goals of the EPICenter project was to advance state of the art for any field, system or technology that became part of the project. In each instance the team identified current state of the art and the barriers to moving beyond it; then the team worked collaboratively to remove the barriers and redefine state of the art.

Throughout the years that brought major changes in scope, budget, and schedule, these same goals were revisited, clarified and enhanced but never abandoned by the students, project chief or the design teams. The successes of the project hinged upon an almost stubborn adherence to the original vision and goals, no matter how articulated. What grew out of these themes was the design for a building that would change the future. It would be a "Living Building" with interdependent systems communicating as a whole. The building would be a living laboratory and a teacher of the values embodied in bricks and mortar.

This project was funded through two US Congressional appropriations to the National Institute of Standards and Technology. The fiduciary duty of the recipient is to disseminate the lessons learned. As you review this report, you will discover what the project management and the design team accomplished: the process is also a teacher.



PROJECT HISTORY

- 1.1 HISTORY NARRATIVE**
- 1.2 EPICenter GRAPHIC TIMELINE**



1.1

HISTORY NARRATIVE

Kath Williams Ed.D.



The research and development of the "Green Building" project at Montana State University encompassed seven years, three major scope changes, exploration of privately-held and publicly-owned building sites, and innovative, "Plus Ultra" work by a host of collaborators. What has resulted is the:

- Advancement of the sciences of sustainability and interoperability
- Development and demonstration of four "green building technology" prototypes
- Design of a "Living Building" (holistic, integrated) system
- Development of new materials and selection methodologies (resource mapping, Baseline Green, and waste stream products that improve the economy)
- Specification of a unique commissioning procedure, all of which can change the way buildings are designed, built, operated, and maintained in the 21st century



■ Planning Workshop for MSU "Green Building"
■ BNIM Architects

Additional noteworthy achievements have been in the areas of community improvement through technology transfer, the development of local industries, protocol development for productivity research, and software for teaching "green chemistry." Given the mission of a university, perhaps the most important contribution this project has made is the positioning of now-experienced students in a blossoming technical arena, green building and sustainable technologies.

The original Montana State University visionaries—Robert Swenson, Jerry Bancroft, and Peter Perna—saw the opportunities in a green building project. When the National Institute of Standards and Technology offered grants for the development of "Green Building Guidelines" in 1993, Montana State University responded with Peter Perna as principal investigator. As one of four recipients of \$200,000 grants, MSU conducted a national search for an architect. Bob Berkebile of BNIM Architects, Kansas City, Missouri, was selected to develop the concepts and lead the international team of experts in energy, water, power, materials, design and building performance.



History Narrative
Kath Williams

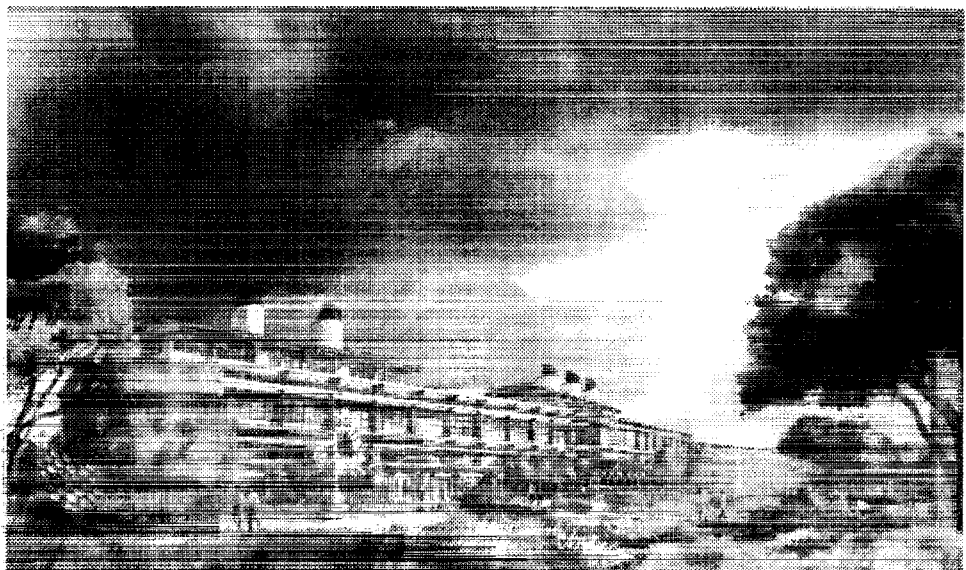


The original team set about improving state of the art in each process or technology. They quickly discovered that understanding the barriers to change was critical in creating a new state of the art. About this time, Berkebile received a gift from a friend that gave the team a name for their new methodology. The gift was a beautiful ceramic tile inscribed with the words: "Plus Ultra" (Latin for "more, beyond").

With the philosophy of going "more, beyond," the initial team defined the concepts of sustainability, embraced the goals of energy efficiency, adopted a new collaborative approach to design, and developed a new vision for the built environment that included the study of human factors. These can all be listed as achievements of the National ReSource Center (NRC) concept.

What grew from the leadership of this team and a unique collaborative effort was the conceptual design of the 47,000 square foot National ReSource Center in the privately-owned technology Park. In 1995, as a result of a second NIST grant, the team was able to develop new tools and technologies that advanced resource efficiency.

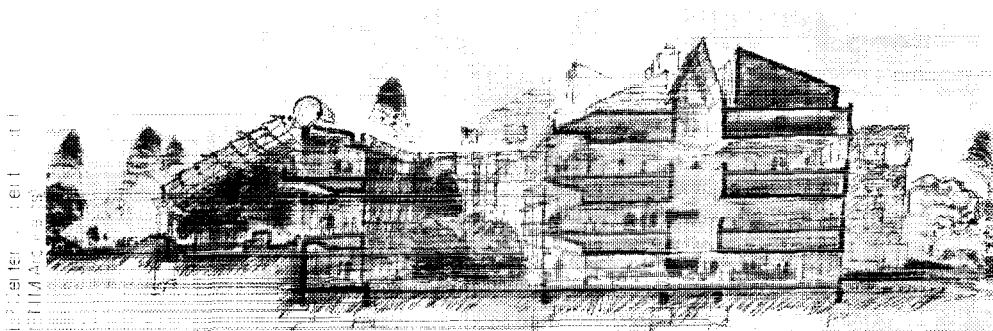
CONCEPTUAL DESIGN OF THE
NATIONAL RESOURCE CENTER
(BNIM Architects)



While the MSU project leadership searched for a tenant who wanted a "green building" as a headquarters, a parallel construction project was underway on campus. During the summer of 1996, student leaders on campus developed an initial proposal for a new classroom/laboratory building that would serve also as an extension to the overcrowded student union and the library.

About the same time, support also came from US Senator Conrad Burns who introduced legislation in Congress for \$1.2 million in research and development funds. Assigned to the NIST budget, these funds were appropriated for the research and design of the National ReSource Center. When plans for the tenant base in the NRC failed to materialize, Vice President of Research Robert Swenson saw an opportunity to combine the student-led, classroom/laboratory project with the "Green Building" project. He appointed Assistant to the Vice President Kath Williams as project chief. With leadership from Associated Students of MSU President Jim McCray, the students voted a fee upon themselves to support a combined green building/classroom/laboratory project.

Gaining Montana legislative support for the building project, which would now be constructed on state-owned property, fell to Vice President of Administration and Finance Robert L. Specter, the student lobbyists, and Director of Facilities Services Robert Lashaway. Green education on a statewide level had begun and, in April 1997, the Montana Legislature granted approval to build a \$19 million project, but approved no capital or funds for operations and maintenance.



Because of great student interest and financial support, President Michael Malone appointed a non-traditional planning committee with 50 percent student representation. After confirming BNIM and Place Architecture of Bozeman as design team leaders, the committee assessed the campus need to house the Center for Computational Biology, the Center for the Discovery of Bioactive Compounds, and multi-disciplinary classrooms, laboratories, and informal student study spaces. Programmatically, the chemistry department needed to be housed in adjacent space bringing the total square footage to over 250,000.

The project goals of integrating research and teaching, making the process of scientific discovery accessible to all students, and building the most resource-efficient facility on the planet evolved from the basic MSU mission and from lengthy discussions within the planning committee. The project name became the EPICenter, Educational Performance and Innovation Center. The vision was that the lessons learned from the building, which would itself be a teacher, would radiate from the center of MSU's campus.

The guiding principle of Plus Ultra fit appropriately with this vision and led the design team to create a model building concept. They applied the concept of integrated design. They provided an environment that would support the advancement of building operations, maintenance and technologies, and discovered innovative methodologies that would make the EPICenter phase of the project a success. Industries, students, community members, designers, and city officials who shared an interest in advancing green buildings and sustainable technologies and systems were invited to participate in all aspects of the project: web site, forums, workshops, etc.

"Maximizing opportunities" was the mantra adopted by project chief Kath Williams. By active participation in the US Green Building Council, by developing partnerships with green industries, and through the services of Gottfried Technologies (now WorldBuild Technologies), a strategic plan for a research and development program was established. An additional congressional appropriation of \$5 million, introduced by Senator Conrad Burns and supported by Senator Max Baucus and Representative Rick Hill, funded the green building technologies development program. A diverse selection of industries came forward to participate in the demonstration program. The NIST appropriation was included in the FY97 budget of

the National Institute of Standards and Technology and assigned to the Building and Fire Research Laboratory. Dr. James Hill, Chief of the Building Environment Division, was responsible for and contributed to the project throughout its progress. Kath Williams and Bob Berkebile guided the process of RFP development, advertising and the selection of the Industry Partners R&D program.

Fisher Hamilton Inc. was selected as the first industry partner and began work on an energy-efficient fume hood, now called Concept 2000. Other partners—from small Montana firms to large national laboratories—answered the call for proposals and subsequently were asked to join the research and development program, the results of which are the substance of this report and the Technical Reports. Because the project had economic development as a goal, emphasis was placed on recruiting Montana and regional firms to participate. MSU's TechLink project was instrumental in identifying appropriate regional partners, such as CHA Corp., Wyoming Sawmills, and the University of Idaho/Boise Cascade team.

In 1998, a formal industry partners demonstration program, developed by WorldBuild Technologies, brought letters of intent from over 100 businesses. Over 30 visited the campus, attending one or two-day collaborative sessions.

As the EPICenter conceptual design process was completed in mid-1998, three forces came into play that changed the shape of the future: 1) Because of the need for campus research space and because student funds were being assessed, MSU administrators backed away from supporting the large project and asked that a "shovel be put into the ground." 2) Research and development partners could not accept the liability of prototype products and systems being demonstrated on a 250,000 square foot scale. They saw a need to approach other universities for testing opportunities while proposing the first commercial application be in the EPICenter. 3) Departure of key MSU administrators found the project struggling to remain a university priority. With the exception of President Michael Malone, none of the 1998 President's Executive Council was involved in the project's vision or development.

The size of the proposed EPICenter—which would have been the largest state building in Montana, and the perceived complexity of the facility's integrated systems drew skepticism. Fears abounded about the expenses of operating and maintaining such a facility. And many doubted the plausibility of raising some \$50 million in a two-year period.

Ultimately, the 1999 Montana Legislature approved the program as an acceptable alternative to low-bid statutes for building materials and technologies but not for general contracting services. The exemption from the requirements of Title 18 reads as follows:

Section 4. Exemption of certain projects. Conditions...

(2) (a) It is the intent of the legislature, with regard to the classroom/laboratory building authorized in section 4, chapter 469, Laws of 1997, that the department of administration contract as provided in this subsection (2). The department shall contract for combination of services, materials, and labor related to innovative building technologies, not otherwise expressly allowed under Title 18, if the innovative technologies:

have the potential to produce energy or operational savings for the state over the life cycle of the building;

demonstrate the use of recycled material;

demonstrate the use of indigenous material for which a new local, regional, or national market may be developed.

(b) The conditions in subsection (2) (a) must specifically apply to individual building systems or components and not to the general contract for construction or for any project service, including design. The terms, quantities, and conditions related to the innovations must be negotiated by the department in the best interests of the state and must provide that there is no express or implied commitment or state appropriations for construction, operations, or maintenance.")



EPICenter Concept Sketch
(Place Architecture)

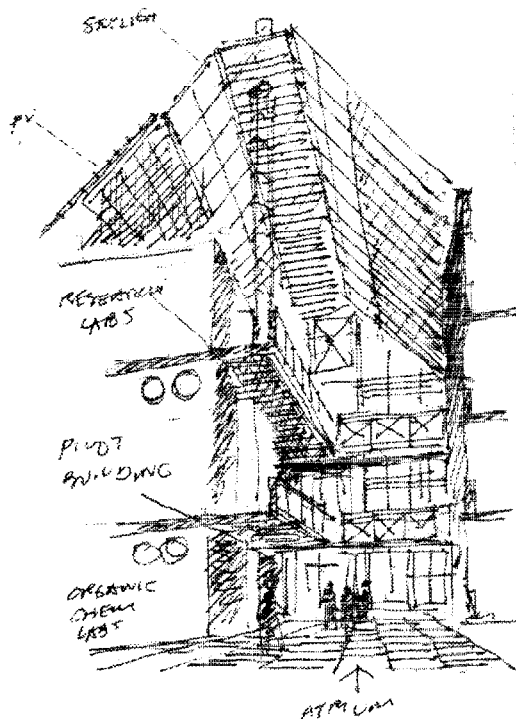
EARTH SQUARES

The project team recognized these pitfalls yet adopted a "hit a home run" strategy and attempted to create a facility that would match the project's extraordinary goals. Lacking allocated development resources, the team identified and approached potential outside donors. As the project changed in size, scope, and occupants over a three-year period, the fundraising strategy was revisited, modified and redirected. In the end, however, no outside funds were pledged.

To address campus concerns, the MSU planning committee voted unanimously to develop a pilot project from the funds in hand that would be a stepping-stone to the EPICenter. Conceptually, it would allow for the testing of the technologies, relationships, and address immediate campus needs. The planning committee presented a \$12 million pilot project concept to MSU's President and his Executive Committee (PEC) in December 1998. A decision was made by the President and the PEC to divide the project into two components. The NIST research and development program would continue with Kath Williams as executive director and Cecilia Vaniman, MSU University Planner, would lead the construction project.

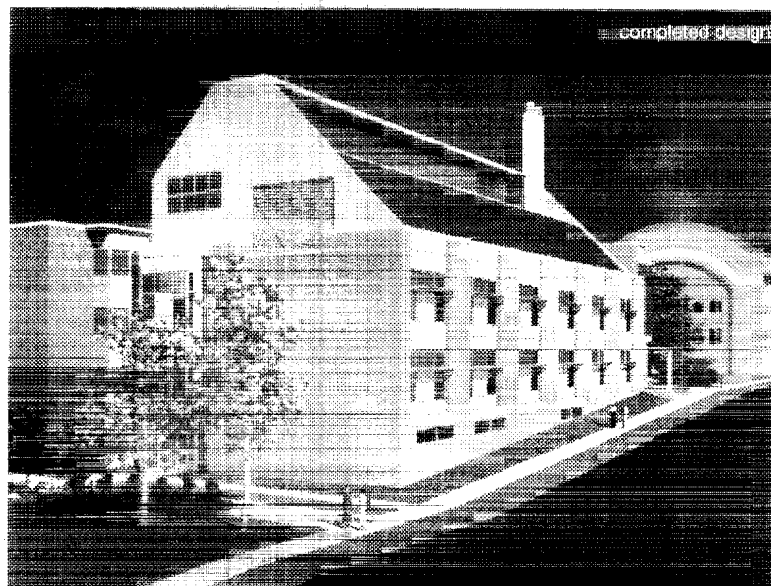
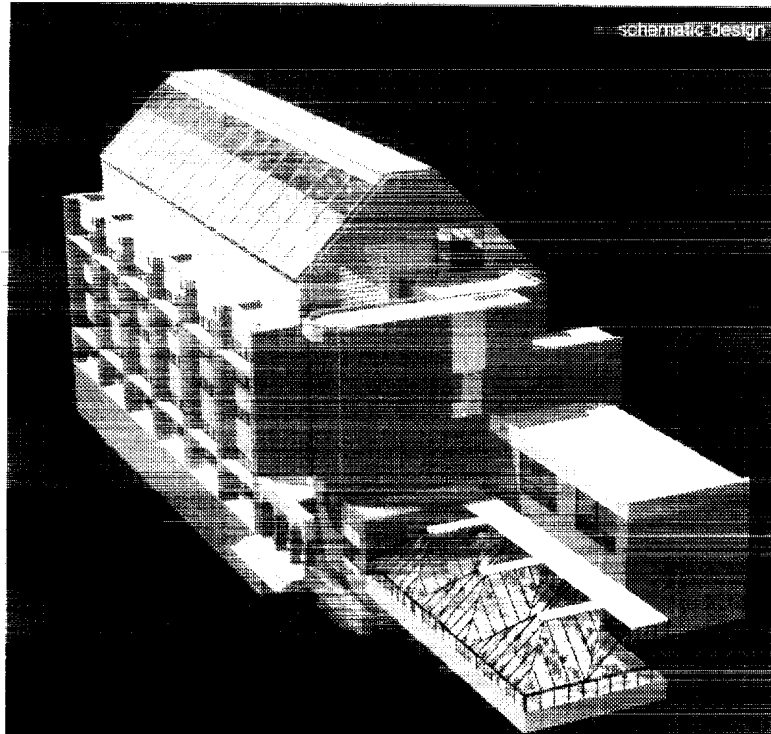
Chemistry department chair David Dooley was appointed to preside over the traditional university building committee composed of the user group, facilities services personnel, and two students. Within months, however, he was appointed MSU's interim provost and Paul Grieco was named building committee chair. Without an expanded budget, this committee changed the pilot project to include:

- a 30,000 square foot addition (the Pilot building) to Gaines Hall, the existing chemistry building
- a 3,500 square foot renovation of the freshmen chemistry teaching laboratories in Gaines
- the renovation of the basement of Lewis Hall to meet the immediate needs of the Center for Computational Biology



Architectural Perspective through EPICenter Pilot Building
JNM Architects

Demolition began in Lewis Hall in December 1999 and in Gaines Hall during the late spring of 2000. For both of the renovation components, industry partners in the demonstration program provided "green" materials paint, light fixtures, certified wood casework, flooring, and insulation—at a discounted price. For example, the new Lewis Hall carpet is being reused after ten years in Chevron, Inc. headquarters in San Ramon, California. Milliken Carpets refurbished the materials and provided them as "EarthSquares." Certified sustainable wood casework was provided by Fisher Hamilton and installed by ISEC Inc.. Herman Miller provided ergonomically designed workstations, complemented by the electric lighting strategy of Clanton and Associates. Both renovation projects were completed and occupied before the fall semester began in 2000.



Computer Renderings of the EPICenter Pilot Building
(BNIM Architects)

Although going “more, beyond” requires constant reevaluation and flexibility, some changes hindered the advancement of the project. Soon after the transition to the pilot project phase, Place Architecture (Bozeman, Montana) chose not to continue as architect of record. Immediate action by the project management yielded special permission from the State of Montana for BNIM Architects to become architect of record. The role of CTA Architects Engineers of Billings, MT was expanded to fill the voids on the collaborative design team.

The design of the Pilot building (the addition to Gaines Hall) has been an achievement in and of itself. Envisioned as a “Living Building,” a holistic approach was adopted by the collaborative, Performance team led by BNIM Architects. The result is believed to be the most energy-efficient fume-hood-intensive laboratory building ever designed. The building will allow the testing of green building technologies and methods at a prototype scale in an environment that will provide unprecedented access to real-time data. Industry partners Johnson Controls and Phoenix Controls have pooled resources with the Performance team to deliver a Plus Ultra building monitoring design and system.

As a pilot project, the Gaines addition provides an opportunity for refinement of these concepts, prototype products, processes, and integrated systems so that the demonstration of concepts, goals, and values garner even greater global support for the larger EPICenter. In the spring of 2000, MSU administration delayed bidding and construction of the Pilot building until 2001.

In order to complete the research and development portion of the project, field testing of the prototypes was essential. Project director Kath Williams worked with MSU Director of Safety and Risk Management Jeff Shada to identify an appropriate installation site for the new technologies. Four prototypes—Fisher Hamilton’s Concept 2000 fume hood, Lawrence Berkeley National Laboratory’s low-flow fume hood, CHA Corporation’s air scrubbing system and Solar Design Associate’s hybrid solar collector Phototherm—have been installed for continued testing and demonstration at MSU’s Safety and Risk Management facility in the Advanced Technology Park, the site where the project began. Johnson Controls and Phoenix Controls developed a building monitoring system to gather performance data that will be made available through the prototype manufacturers.

Achievements in the NIST-sponsored research and development project have been noted throughout the nation and are summarized in “Results.” Perhaps the single largest achievement of the EPICenter project was that it touched so many individuals who now continue with their own work using a Plus Ultra framework.

One of the key successes of the project was dissemination through technical, educational, and general public conference presentations to a variety of audiences. This allowed for discussion and improvements in the systems, protocols, products and design.

The EPICenter project had an obvious “ripple” effect on the campus. The value to students and faculty who participated in the process is a Plus Ultra achievement itself. The project provided several opportunities on campus for interdisciplinary and cross-disciplinary research projects and also strengthened ties with MSU’s affiliated campus, MSU-Northern in Havre, Montana.

Discussions of sustainability have radiated throughout the state of Montana because of the EPICenter project. Design team members and the project director have been frequently requested as speakers for Montana AIA, Chambers of Commerce, and Montana Contractors Association events.

MORE BEYOND

The effects of the EPICenter project are expected to continue well beyond the NIST project termination date of September 30, 2000. Funds have been set aside to monitor the results of the NIST prototypes currently being operated, validated, and improved at MSU's Safety and Risk Management Facility in the Advanced Technology Park. The project team will share the project's successes and "lessons learned" in a one-year-afterward report, publications, conferences and in their own professional activities. Industry partners, from large corporations like Fisher Hamilton to small firms like CHA Corporation and Headwaters Composites, have changed the way they do business because of the EPICenter project. They have gone "more, beyond."

Your critique of the concepts, systems and products reported herein are encouraged—as well as your successes in discovering more sustainable approaches. Please let us hear from you at jhill@mict.nist.gov and bnim.com.

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EPICenter GRAPHIC TIMELINE

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PLUS ULTRA



Programming workshop for MSU Green Building



Design Charrette #1 for MSU Green Building

Phase 4 Concept Design for the National Resource Center complete 47,000 sq ft privately owned technology park

"Plus Ultra" introduced and adopted for the project

PHASE 1 ENDS

PHASE 2 BEGINS



Design Charrette #2 for EPICenter



Initial planning for new classroom/lab building

MSU selects charrette for new classroom/lab building

design charrette for EPICenter

NATIONAL RESOURCE CENTER

6/93

MSU submits phase 1 planning grant proposal to NIST

NIST funds Phase 1 Proposal \$200,000

NIST funds additional \$200,000 to expand phase 1

6/94

2/94

EPICenter PROJECT

10/96

US congress appropriates \$1.2 million to NIST budget for a green building demonstration

State legislature authorizes \$19 million for a new MSU academic building but no funds for operation and maintenance

4/97

8/97

7/96

US Congress approves additional \$1.2 million to NIST budget for a green building demonstration for MSU

US Congress approves additional \$5.0 million for green building technology research program

MSU students vote to increase their fees for new green classroom/lab building

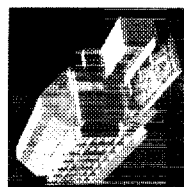
MSU receives initial proposal for new green classroom/lab building

MSU submits phase 2 grant proposal to Congress

The project is named MSU EPICenter Educational Performance and Innovation Center

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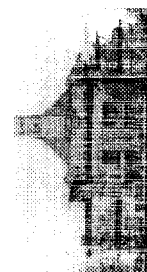
EPICenter Graphic Timeline
Kathy Achelpohl +
Phaedra Svec



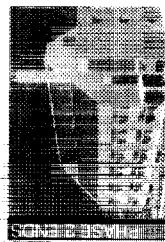
**Pilot building
schematic
design complete**



external,
or g
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build up



ERICenter concept complete
\$50,000 if on ASU campus



**Pilot building
construction
documents
complete**



President Clinton lined item vetoed the additional \$5.0 million for green building technology + research program

US Congress reapproves \$5.0 million for Green Building Technology + Research Program

EP Center
Planning
Committed
votes to
develop a
\$30,000 st
pilot project
and to con-
tinue fund-
raising for
EPICenter.

- Pilot building
- renovation of Games Hall
- renovation of Lewis Hall

Pilot building bid date shifted to 2001

At the same time, the need to install practices that advanced technology park

စာအုပ်အမျိုးအစား

Center
Office and
project
closed



**RE-EVALUATING PROJECT
COURSE FOR EFFECTIVE
high-study
appropriate strategy for test-
ing technology and research
meet immediate demands
for classroom success at MSU
MSU changes curriculum**

2



CONCEPTS, TECHNOLOGIES AND METHODS

- 2.1 A "PLUS ULTRA" DESIGN PROCESS
- 2.2 TECHNOLOGY TRANSFER AND SELECTION
- 2.3 HARNESSING ENERGY FROM NATURE
- 2.4 THE FUTURE OF MATERIAL SELECTION
- 2.5 CONSTRUCTION METHODOLOGIES
- 2.6 IMPROVING HUMAN HEALTH AND PRODUCTIVITY
- 2.7 ZERO POLLUTING EMISSIONS GOAL
- 2.8 THE LIVING BUILDING

2.1

A 'PLUS ULTRA' DESIGN PROCESS

Jason F McLennan



"No problem can be solved by the same level of consciousness that created it."

Albert Einstein

Perhaps the most important goal of the MSU EPICenter project was to change the way in which buildings are designed, built, operated and maintained. The design team realized that to achieve this goal it had to begin by re-examining the design process itself.

Early on in the project Bob Berkebile selected the term "Plus Ultra" to serve as the guiding spirit for a new process of decision-making and design. Plus Ultra means "more, beyond" in Latin. It became the philosophy for this new design process and for all those who were involved in efforts to push the barriers of their respective fields. Plus Ultra was not only a vision statement, it was also a methodology, repeatable in the steps necessary to attain it. The methodology that the project team used to define Plus Ultra had three simple steps applicable to any process, technology, or field of study:

- Identify state of the art in any field, system, or technology
- Identify the barriers to "moving beyond" state of the art
- Remove the barrier and redefine state of the art

With the Plus Ultra methodology as its guide, the EPICenter project became an opportunity to create new products, technologies, and processes that would provide the building industry with a new benchmark against which to measure environmental health and economic performance. The Plus Ultra methodology was also an opportunity to turn convention on its head and begin the course correction necessary to protect the health of the environment for future generations. But, most importantly, this philosophy provided an opportunity to prove that this course correction was not only necessary but attainable.

THE TRADITIONAL DESIGN PROCESS

While architectural design is by its nature an iterative process, it isn't a particularly inclusive one and often involves only a narrow field of specialists who perform their work in relative isolation. Architects, engineers, contractors, and other building professionals often do little to understand the interconnectedness and interdependency of the issues that affect each other. Nor do they try to understand the ways in which they could improve each other's performance by altering their own process. Instead, many seem stuck in the inertia of "the way things have always been done" and as a result they impose constraints upon each other, making innovation and improvements to efficiency almost impossible. The result is often an adversarial relationship with competing interests.

The Plus Ultra design process therefore had to be one in which the traditional barriers between the design professions are broken down and everyone is involved in the design process from the beginning. In addition, the Plus Ultra methodology demanded that the circle be widened to include all stakeholders and individuals not normally a part of the design process. Examples include: artists, historians, ecologists, sociologists, educators, physiologists, and biologists. This was done to reflect the reality that a successful built environment, one that respects the natural environment while improving human health and productivity, needs knowledge outside the circle found in the traditional design professions.



In the summer of 1993, Bob Berkebile journeyed to Antarctica's McMurdo research station in order to examine ways in which that facility and community could be transformed into a model more consistent with the goals of the environmental research taking place there. At McMurdo, Berkebile realized the value and richness of synergistic efforts that occur when traditional lines between disciplines are blurred. Due to limited funding, scientists from entirely different research backgrounds (such as geologists, biologists, physicists, and chemists) shared computer and communications equipment in the common computer lab/library space. The synergy resulting from this close cross-discipline collaboration was remarkable: major breakthroughs were achieved as each received input from individuals with entirely different perspectives and knowledge bases. As in nature, the power of diversity shined through to provide the most robust, elegant solutions. This powerful example became the guiding model for re-shaping the design process on MSU's EPICenter project.

EXPANDING THE DESIGN TEAM

The EPICenter project began by including all members of the design team and all the stakeholders in the building (students, scientists, faculty) from the beginning of the design process. The Plus Ultra methodology recognized the need for mechanical engineers, structural engineers, and specialty consultants to be involved from the onset, each giving vital input, setting goals and sharing their concerns and viewpoints. The project attracted a unique team of leading innovators, including industrial ecologists, indoor air quality experts, artists and historians, all with something to add to the quality of the project. Over the life of the project those that helped to guide the process numbered in the hundreds and included MSU students from a number of colleges.

This expanded team sought to create a collaborative, holistic design approach that found the "highest common denominator solution, integrating ambitious goals for zero-polluting emissions, resource efficiency, daylighting, synergistic learning environments and ecosystem restoration" (Hilary Dustin, Place Architecture).

HOLISTIC THINKING

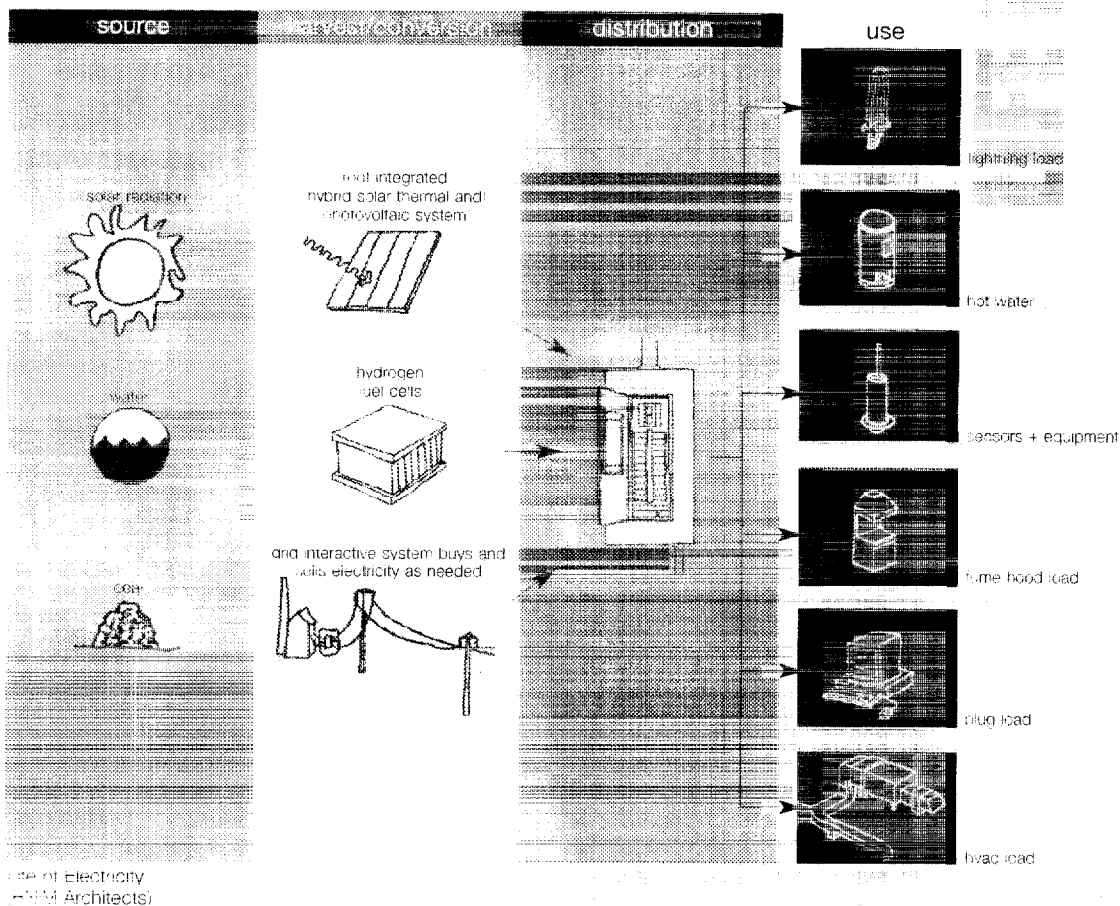
Changing the way buildings are designed depends not only on including a greater variety of individuals on a project but also on how those individuals think and solve problems. The Plus Ultra methodology demanded that design team members "think holistically" and solve problems on a whole-system basis rather than solely through western scientific reductive methods (although these were used as well). Holistic thinking is inclusive thinking. It views things from a total systems perspective and then works backwards, always asking the question: "What happens to the whole system when we make changes in one area?" The core design team was fortunate in attracting many individuals who use holistic thinking principles in their daily practice. Some of these individuals included Ron Perkins and Peter Rumsey of Supersymmetry, Hal Levin of Building Ecology Research Group, and Dale Sartor of the Lawrence Berkeley National Laboratory.

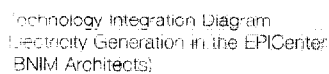
Holistic thinking is an approach in which all aspects of a building's operation are considered from a life-cycle perspective, whether it is water, waste, light, heat, structure, electricity or humidity. The next step is to consider how each of these components can interact to create smaller and less energy-intensive systems. Designing a building with proper daylighting, combined with efficient lighting and controls, can reduce the size of the mechanical system. This in turn means smaller transformers and smaller emergency generators which usually more than pay for the lighting and control improvements. If judged purely on the payback that the lighting and control systems alone generate, the upgrades may not look cost-effective and a huge opportunity would have been missed. As Joseph Romm states in his book *Lean*

and Clean Management. "Becoming lean and clean through systems thinking requires making connections in time (through life-cycle analysis) and in space (through teamwork)."

With advances being proposed in fume hood design, ventilation, and materials, holistic thinking was required to ensure that at no point were human health and comfort being compromised. Sick Building Syndrome, after all, arose because designers did not properly understand how air quality and health could be related to material selection, building construction practices, and energy efficiency.

Early on in the design process, Jason McLennan developed a series of "cartoons" that illustrated the holistic thinking process as it related to "flows" within the building. These cartoons, which came to be known as "life of" diagrams, were utilized by the design team throughout the process and were further developed by the team into a series of schematic diagrams that blended these principles with architectural features.





The holistic thinking process inevitably produces a sequence of operations or logic of its own that could be compared to the mathematical order of operations. In a mathematical equation proper solutions can only be achieved if individuals solve the problem in the proper sequence. Holistic thinking adopts the same logic. If the sequence is performed in the wrong order, efficiency and performance have been sacrificed. In an article published by Jason McLennan in the 1998 American Council for an Energy Efficient Economy (ACEEE) conference proceedings, this holistic thinking process was summarized as follows:

CHARRETTES

■ Identify and Quantify Flows

Identify which systems within a building need to be improved in terms of efficiency or performance and understand how this particular system fits within the whole.

■ Reduce Demands

Wherever possible minimize or eliminate demands on the system using the "why" process.

■ Harness Nature to Meet Reduced Demands

Wherever possible use "free energy" to meet the reduced demands. Free energy could include passive solar heating, natural convection, the use of waste heat or water from another system, etc.

■ Use the Most Efficient Equipment

Only after loads have been reduced and "free energy" harnessed should the most efficient "right-sized" equipment and systems be used for operation.

■ Monitor, Measure and Repeat

Repeat steps 1-5 until performance cannot be improved. Track building performance over time to understand how the building truly performs and to inform future designs.

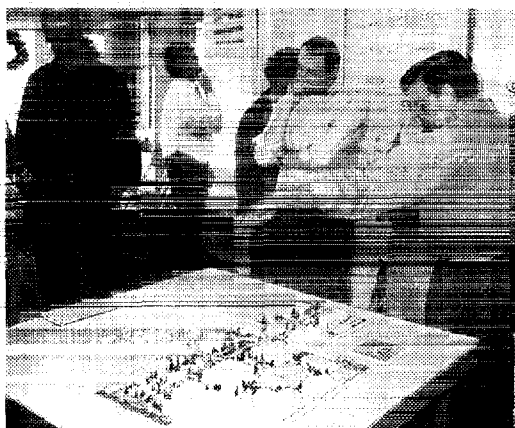
THE CHARRETTE PROCESS

Charrettes have long been part of the architectural design process, but typically involved only designers and sometimes the client. Often charrettes addressed pure "architectural issues" of program and design response. In the EPICenter project the charrettes became forums for the discussion of a myriad of issues. Like for instance:

- How to select building materials that transform the local waste stream to new, durable products that improve the local economy and the environment

- How to design a closed-loop water and waste system while balancing human health concerns

- How to design a flexible structural system to allow for the lowest possible pressure drop in the building's mechanical systems



EPICenter Charrette
(BNIM Architects)

In a short amount of time, working in synergy across disciplines, the team was able to develop integrated elegant solutions that removed the barriers in the way of achieving the project goals.

Throughout the project different groups of this enlarged design team met in a series of "charrettes" or design sessions in Montana, in Kansas City in the office of BNIM Architects, in Boulder, Colorado, or electronically from London or Antarctica. At these charrettes the design team had the opportunity to collaboratively seek design solutions for the project and check project process. These design charrettes were organized by a member of the archi-

tectural team (initially Chris Kelsey and Hilary Dustin, and later Kathy Achelpohl), who set agendas and made sure that each participant had a chance to present their particular issues. The importance of the charrette was the synergy of a diverse team collaborating in the decision making process at one time and in one place.

The charrette process allowed the entire team to participate in setting goals for the project. This is a critical part of any project and especially the Plus Ultra design methodology because it ensures that all members of the team are working toward commonly agreed upon goals. The project goals, which should be documented in a continually updated design-intent document, can then be used as a checkpoint to measure progress. In the case of the Pilot building, the final destination for the design-intent document was its embodiment in the Plus Ultra commissioning process (see Technical Report) that will allow MSU to track the performance of the Pilot building by measuring the built facility compared to the design intent.

TEAM COMMUNICATION

To reduce the environmental impact of travel most of the communication on the project was accomplished electronically. The team made extensive use of e-mail, telephone, videoconferencing, and web-based communication tools to exchange information and ideas. In order to finalize the design of the Pilot building, the team had regular videoconferences between Kansas City and Bozeman to share drawings and make decisions. The team also made an agreement with BlueLine Online who provided a web-based project management program that allowed the team to share drawings and documents via computer. Due to the large size of the team this became an essential part of the project communication system and minimized the time needed to send faxes and shipments, thus minimizing the associated cost and environmental impact.

Despite the success and ease of these communication tools however, the team found that nothing compares to the power of face-to-face interactions. Charrettes therefore continued to be necessary at critical junctions in the design process.

TEAM ORGANIZATION

Key work groups included the following teams (see Technical Reports):

- Water and Waste**
- Performance**
- Materials**
- Power**

While there was some concern about breaking the larger team into smaller groups, it did not prove to be a hindrance to the project. To prevent issues from being lost in the shuffle, the core design team members were assigned to the four teams so that information could be shared from group to group and results of the work group's products were posted on the project website. In most cases Kathy Achelpohl and Jason McLennan served in this role.

Perhaps the most active and interdisciplinary team was the Performance team, which covered energy efficiency, mechanical systems, passive heating and cooling, daylighting and electric lighting, and human health and productivity (see "Harnessing Energy from Nature" and "Improving Human Health and Productivity"). By their nature these areas needed the most coordination and could benefit most from integrated design solutions.

THE IMPORTANCE OF LEADERSHIP

Leadership was essential because, despite all its lofty goals, the EPICenter Pilot building project had to adhere to a tight budget and schedule. As a result, decisions sometimes had to be made even before all the research could be completed in an area or before every member of the team had a chance to give input. In many cases, tough decisions had to be made to meet the schedule and budget requirements.

The success of a project of any type depends on the clarity and vision of its leaders and their ability to share that vision. On the EPICenter project Kath Williams of Montana State University and Bob Berkebile of BNIM Architects provided this leadership. Those who were inspired by this leadership and set out in their own way to make the vision a reality were numerous and their contributions many. Kath Williams often compared the EPICenter project to the journey of Lewis & Clark, who, with the help of Sacagawea, explored the country between Missouri and the Pacific. Like Lewis and Clark, the design team explored new ground in a collaborative process of discovery.

INTEGRATED DESIGN

Using Plus Ultra methodology and holistic thinking principles resulted in integrated design solutions more elegant and efficient than those achieved by traditional design methods. Integrated design scenarios solve multiple problems at once in the simplest and most cost-effective way. On the EPICenter Pilot building there were numerous examples of how the Plus Ultra design process resulted in integrated design solutions.

Perhaps the most compelling example is how the structure of the building was designed in concert with the mechanical system, lab equipment layout, daylighting and lighting designs, and architectural program. The solutions to these particular problems were reached during the charrette process through the collaboration of many individuals, including Bob Berkebile, Jason McLennan, Andy VanBlarcum and Kathy Achelpohl of BNIM, Shawn Murray of CTA Architects Engineers, Ron Perkins of Supersymmetry, Nancy Clanton of Clanton & Associates, and Tom Beaudette of Beaudette Engineering, with continued refinements from a host of others. Figure 2.1.1 and 2.1.2 illustrates how the U-shaped structure was designed to embrace the mechanical ducts and also used to organize the plan and laboratory equipment. The double beams that support the floor slabs allow the fume hood ductwork to be raised higher in the section, freeing up area needed to maximize daylighting in the laboratories. Additionally, the U-shaped elements are used as part of the building's lateral force resisting system thereby making the structure more efficient.

Another good example from the Pilot building design is demonstrated in figure 2.1.3 that illustrates a section through the roof of the building. This particular design solution resulted from the need to integrate a 20 kw photovoltaic array (see "Harnessing Energy from Nature"), which was also the roof enclosure, and allow for daylight penetration through clorestory windows into the atrium. The design also had to accommodate a very large, low-velocity, low-pressure air handling system located on the floor level directly below the array.

As these examples illustrate, successful integrated design concepts accomplish several objectives:

- Greater efficiency: each system in the building is working in harmony
- Integrated systems are not easily "value-engineered" out of the project
- Results are more meaningful and beautiful
- Use less material, but do more work
- Flexibility, feedback, and control are increased



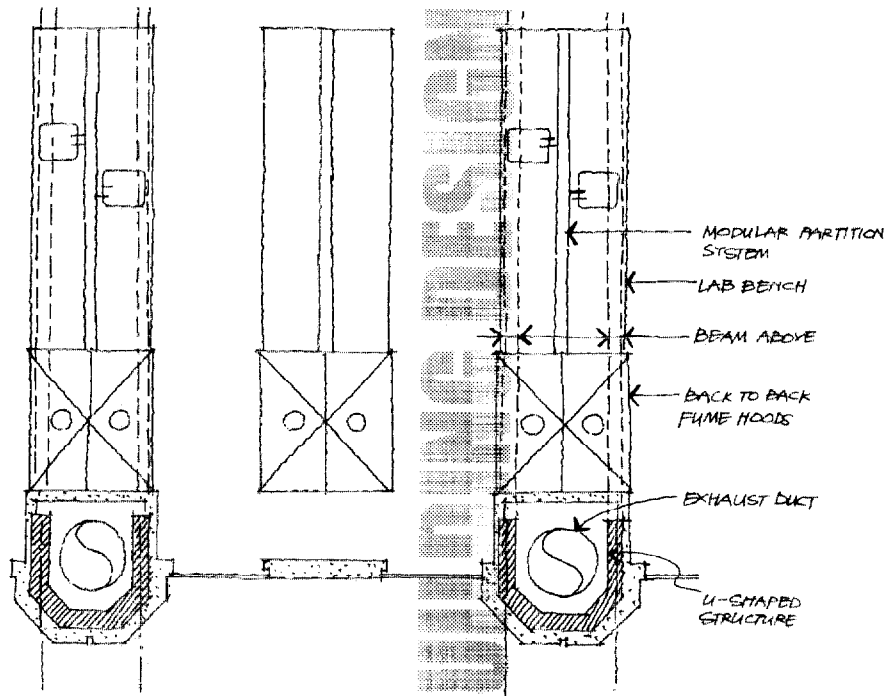


figure 2.1.1
Lab Plan Detail
showing integrated
mechanical/lab
casework design
(BNIM Architects)

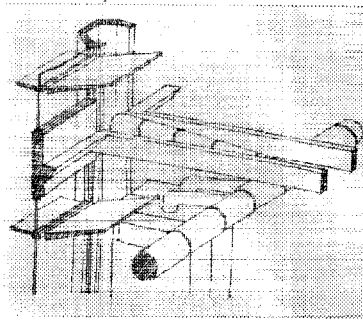


figure 2.1.2
Sketch of integrated
structural/mechanical design
(BNIM Architects)

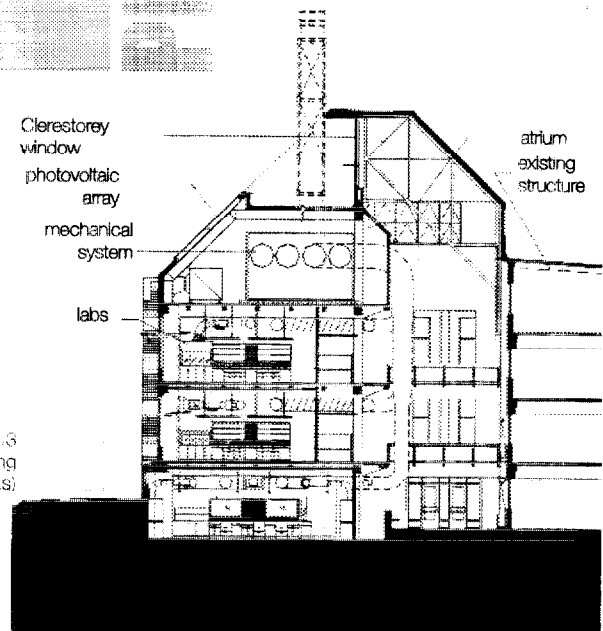


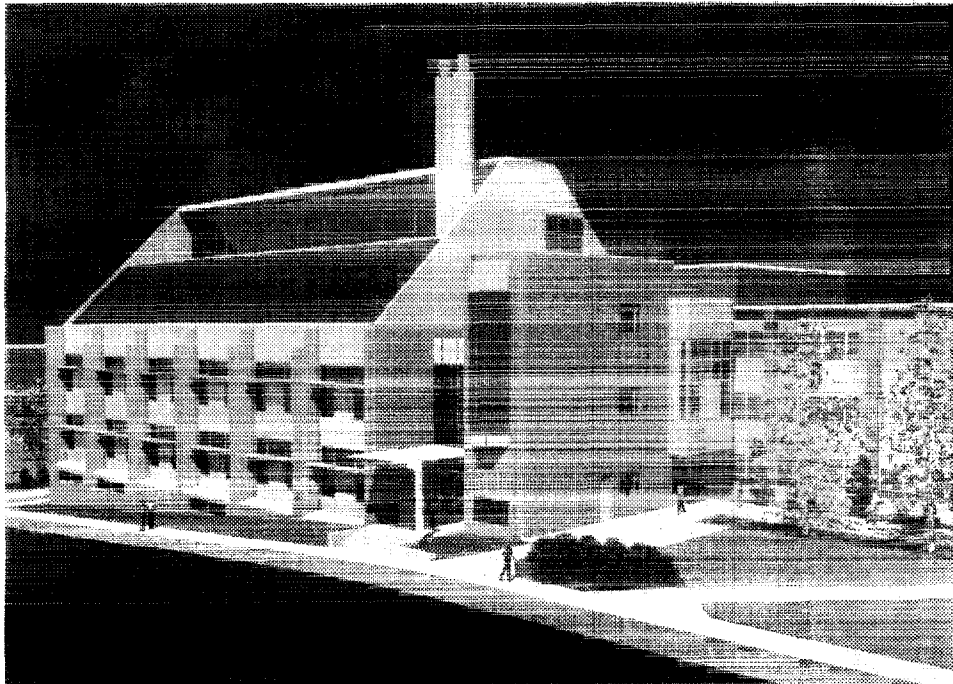
figure 2.1.3
E-Center Pilot Building
(BNIM Architects)

SOME LESSONS LEARNED

While there were many breakthroughs on the project due to the Plus Ultra design process, there were some hard lessons as well. The team learned that there can be too many “cooks in the kitchen” and that quite possibly there is an ideal team size or “carrying capacity” to any project. While the expanded team provided breakthroughs in many critical areas, it also became a serious challenge for the team to manage and track progress on all fronts simultaneously. A slightly smaller team might have been even more successful. Sometimes during the project there were simply too many individuals, too many technologies, and too many things that needed to happen in the time available or for the size of the core management team to handle effectively. In some cases, opportunities may have been missed because of the team’s size and the number of areas in which the team attempted to achieve Plus Ultra status.

The team also learned the importance of having buy-in from all members of the team throughout the history of the project, especially individuals who have the authority or power to redirect or minimize the project’s potential. For the first five years of the project, the design team worked toward the original project goals—which were very clear—and during that time, the goals weren’t questioned even when key MSU stakeholders changed. But, when the project became the EPICenter and later the Pilot building, key MSU players continued to change and participants were introduced who did not help create—and therefore had no allegiance to—the original goals. When this happened, the design team should have stopped their work and reaffirmed the project goals.

The team also concedes that most projects do not have NIST grants to pay for additional experts. The results from an expanded and integrated design process can more than pay for a slightly enlarged and more participatory team if design fees can be expanded at the outset and if the benefits of such an approach are communicated to all stakeholders.



EPICenter Pilot Building
(BNIM Architects)

SUMMARY

In summary, the team learned it is essentially important to:

- Set firm goals at the outset with buy-in from all stakeholders.
- Document the goals in a living design-intent document that is continually updated and revisited and reaffirmed as new key stakeholders are introduced.
- Put in place communication and decision-making protocols early and adhere to them.
- Scale the size of the expanded team to an appropriate level as compared to the size of the core management team.
- Schedule design charrettes that bring all stakeholders together at regular intervals.
- Use holistic thinking principles to produce integrated design solutions.
- Return again and again to Plus Ultra.

2.2

TECHNOLOGY TRANSFER AND SELECTION

Jason F. McLennan + Kathy Achelpohl AIA



"We have in place in America the technological ability to reduce our overall energy consumption by nearly 80 percent."

Paul Hawken

Part of the mandate of the NIST grant was to identify and help develop technologies that have the most potential to change the performance and environmental impact of buildings. Emphasis was placed on technologies that were near commercialization and needed an additional "boost" to reach maturation. In later stages the technology selection process was to play an important role within MSU's Industry Partners program (see Technical Report). Over the course of the project a host of technologies were identified, with different levels of investigation into their appropriateness for funding depending on their potential impact and a variety of other screens. Some of the factors that influenced eventual funding included:

- Distance to maturation
- Amount of funding needed to reach maturation
- Potential to reduce environmental impact
- Potential to improve human health and productivity or safety
- Appropriateness to the EPICenter project specifically and Montana regionally
- Viability as a commercial product
- Willingness or ability of inventor/owner to contribute to its development

It is interesting to note that the project team was able to identify more potential technologies than could be funded. Difficult decisions had to be made. Many technologies were not funded, not because they were not promising, but because they did not fit all of the above criteria. In some cases technologies were dropped as the project changed sites and programs. In particular, when the project changed initially from the National ReSource Center to the EPICenter, the focus changed to include technologies that could make the laboratory environment more energy-efficient and safer. Typically BNIM architects made recommendations to MSU concerning which technologies should be funded, then MSU made a final recommendation to NIST. The design team did not endorse all the technologies proposed to NIST for funding as some were chosen directly by MSU because they contributed to advances on campus or in the region.

Several key members were responsible for the identification and investigation of key technologies, including Kath Williams (MSU) and Bob Berkebile, Chris Kelsey, Jason McLennan and Kathy Achelpohl (BNIM Architects).



The design team identified possible new technologies in a number of ways:

Word of Mouth. At the beginning of the project, BNIM did an extensive phone survey of leading practitioners in a variety of fields of interest to the project, including energy generation, daylighting, indoor air quality and air purification, water and waste management, and materials. These phone surveys were invaluable in identifying a large number of leads from reliable sources.

Conferences and Presentations. The design team traveled to a host of conferences to present the ideas for the project and had the opportunity to identify several key technologies. In particular, the connection to the LBNL fume hood was made at the 1998 American Council for an Energy Efficient Economy (ACEEE) conference in Monterey, and a connection with Phoenix Controls was made at EPA's Lab of the 21 Century conference in 1999.

If You Build it They Will Come. One of the most effective ways that technology projects were identified came simply from individuals and organizations that came forward with proposals once it was known that development money was available. MSU-Northern's three projects were among these. Legal notices were published in newspapers statewide, and Kath Williams, MSU's EPICenter project chief, gave many talks on campus to raise awareness of the project.

Internet Research. The Internet served as a valuable resource throughout the project as a source of ideas and inspiration. At points in the project, MSU's project website received 30-40 "hits" a week, many of them from service providers and consultants who wanted to be a part of the EPICenter project.

MSU's Industry Partners Program. As MSU developed their industry partners program, potential research partners, like Fisher Hamilton were contacted. Fisher Hamilton went on to become a partner and had an active role in the NIST R&D program. As part of the program, Fisher Hamilton developed a new more energy efficient fume hood and also assisted LBNL in the development of their low-flow fume hood by providing testing facilities and ultimately constructing LBNL's prototype that was installed at MSU. In addition, Fisher Hamilton was involved in the development of CHA's fume hood air purification system specifically as an advocate to reduce the physical size of the absorber unit to help make the product commercially viable in the laboratory renovation market.

Technology Research Groups. MSU's NASA technology transfer group helped to identify potential research projects in the region, and based on their research and recommendations, CHA, Wyoming Sawmills, and the Boise Cascade/University of Idaho Department of Forest Products became NIST research partners. Additional technology transfer opportunities were identified by the Northwest Environmental Business Council's Montana Coordinator Linda Brander and her group.

THE ROLE OF THE EXPERT CRITIC

While the design team was responsible for the identification of appropriate technologies, the decision to pursue development and award funding for them was not made by the design team alone. Bob Berkebile recognized the importance of hiring "outside critics" to make sure that all decisions on the project where state of the art was being pushed, were made responsibly. The role of the outside critic was of particular importance during technology selection, as the design team did not always have the necessary technical expertise with which to make truly informed decisions. The expert critics on the project changed depending on the topic and often included faculty scientists at MSU, members of the Performance team, or sometimes individuals who had little involvement on the project other than to analyze a particular technology. Critics who played significant roles over the course of the project

Outside Critic Dr. Melvin First with Dr. John
 1999 at the Living Machine in Burlington,
 Vermont (BNIM Architects)



ect included Dr. Melvin W. First, a public health expert from Harvard University; Janet Baum, a lab design specialist; Ron Perkins of Supersymmetry, a mechanical engineer specializing in integrated systems and energy efficiency; Dr. Gerhard Knutson, an expert on air flow and fume hood safety; Hal Levin, a building ecologist and IAQ pioneer; and Dr. Anne Camper, a Biofilm engineer at MSU.

TECHNOLOGY TIMELINE

A complete list of the technologies that were pursued on the project is shown on the following pages. The timeline shows when technologies were adopted, when they dropped off (if they were eliminated), and why they dropped off or how they were included in the Pilot building design. It is interesting to note that some technologies and methodologies were always a part of the project such as:

- Solar aquatic wastewater treatment
- Natural ventilation
- Solar power
- Development of new building materials from waste streams
- Development of a life-cycle-based material selection methodology
- Development of a methodology to evaluate human factors

In terms of the final design for the Pilot building, the most successful technologies were those that centered on building performance in terms of energy efficiency and integrated design. Also successful were the research projects in advanced fume hood design and air scrubbing technology (see below). See "The Future of Materials" and "Improving Human Health and Productivity" for information about the development of new methodologies to select materials and evaluate human factors.

There were some "technology disappointments"—quite unrelated to the technologies themselves—as the Pilot building design progressed. For example, the design team was very optimistic about a new type of wastewater treatment system being developed by a group of MSU scientists who planned to design, build and maintain a prototype system in the Pilot building, but MSU lacked the funding for the bricks and mortar to build the greenhouse structure. MSU sought several EPA grants to pay for the structure but funding was denied. Another disappointment was the hybrid, integrated photovoltaic array to be beta-tested on the Pilot building. When MSU postponed the Pilot building bid date until after the close of the NIST grant, NIST funds were no longer available to pay for the hardware and installation of the prototype, and as a result the photovoltaics were not included in the Pilot building construction documents.

TECHNOLOGY PROTOTYPES

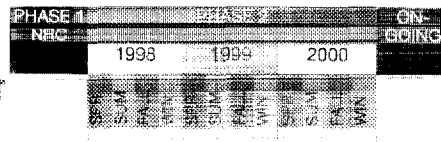
In the end four major technologies received a significant share of the NIST funding for product development and commercialization. LBNL's and Fisher Hamilton's fume hoods and the hybrid integrated PV technology are summarized below and a summary of CHA's microwave air scrubbing technology is in the chapter entitled "Zero Polluting Emissions Goal." All four of these technologies have been prototyped and are undergoing testing in MSU's Safety and Risk Management Facility located at the Advanced Technology Park.

SELECT

BUILDING PERFORMANCE



TECHNOLOGIES PURSUED



AIR AND EXHAUST

Air Scrubbing Systems (Zero-Polluting Emissions Goal)
Photocatalytic Oxidation

Insufficient evidence to proceed with PCO

Microwave Air Purification (CHA)

Prototype installed at MSU's Tech Park in August 2000

Advanced Fume Hoods
LBNL Low-flow Berkeley Fume Hood

Prototype installed at MSU's Tech Park in August 2000

Fisher Hamilton 2000

Prototype installed in MSU's Tech Park in August 2000

ADVANCES IN POWER

Solar Power
Rooftop Mounted Solar Panels

Integrated, hybrid collector had more promise

Stirling Engine

Integrated, hybrid collector had more promise

Integrated, hybrid solar thermal collector

Prototype installed at MSU's Tech Park in August 2000

Hydrogen Fuel Cell

Pilot building bid date shifts and partnership falls through

Wind Power

Wind farm to provide clean Pilot building power

WASTEWATER TREATMENT

Wastewater Treatment Systems

Polar Aquatic Wastewater Treatment -
Living Machine

MSU engineers propose to develop/maintain system

Biological Wastewater Treatment - ATAD
System

Planned to be beta tested in Pilot building Phase 2

Sidestream for Chemical Remediation

MSU engineers test plants to remediate chemicals

Effective Microorganisms (EM)

Insufficient evidence to proceed with EM

BUILDING MATERIALS

Development of New Materials from
Waste Streams

Mine Tailings/Fly Ash CML

Specified for Pilot building

Road Oyl as Floor Material

Not appropriate material for Pilot building applications

High Percentage Fly Ash in Structural
Concrete

Tests for high % fly ash in building structure completed

Fly Ash Concrete

Fly Ash concrete used in Pilot building features

Fly Ash Composite Stone (Headwaters
Composites)

Headwaters product specified for Pilot building

Cast Earth

Dropped - calcified gypsum not waste product in region

Material Selection Strategies

Select Regional Materials (within a 300
mile radius of the site)

Local brick and fly ash composite used in Pilot building

Development of Material Selection
Methodology

Baseline Green to be tested

CONSTRUCTION PROCESS

Zero Waste Construction Practices

Construction Waste Plan specified for Pilot building

Indoor Air Quality Strategies

IAQ strategies incorporated in Pilot building design

"Plus Ultra" Commissioning

Plus Ultra design for Pilot building completed

When the EPICenter project became a fume-hood intensive chemistry teaching and research facility, advancing state of the art for fume hood design was a paramount concern. In this effort, two groups became involved with the project to develop more energy efficient and safer fume hood designs: Lawrence Berkeley National Labs (LBNL) and Fisher Hamilton.

LBNL has developed a promising new low-flow fume hood technology called the "Berkeley Lab High-Performance Fume Hood" that reduces airflow requirements by 50-70 percent, while maintaining or enhancing user safety. The hood uses a "push-pull" approach to contain the fumes and exhaust them from the hood. Small supply fans located at the top and bottom of the hood's sash, or "face," gently push air into the hood (see figure 2.2.1). These low velocity airflows create an air divider that separates the fume hood interior from the exterior using low-intensity, low-velocity airflow (unlike an air curtain approach that uses high-velocity airflow). LBNL's air divider approach of separating and distributing air leads to greater containment and exhaust efficiency. In addition, the air distribution is designed to:

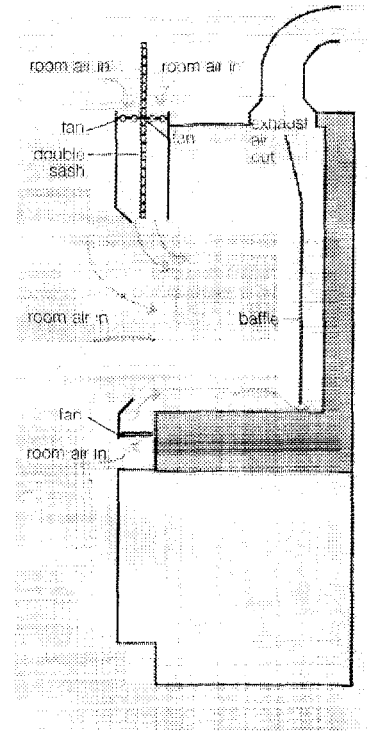
- Push clean room air into the breathing zone of the operator
- Reduce or eliminate dangerous eddy currents and vortexes
- Provide more efficient push-pull ventilation

LBNL's research team applied an iterative process of discovery and refinement using computational fluid dynamic (CFD) modeling, bench top fabrication and testing, prototyping components, and full-scale prototype fabrication and testing. Developing their fume hood into a field test-able prototype condition required a number of steps. Some of the significant activities included:

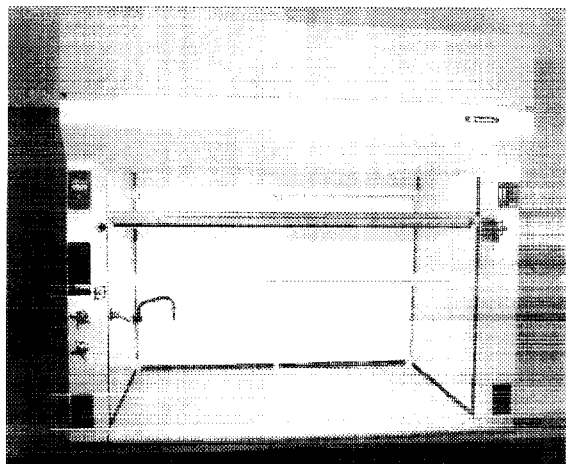
- Review of hood design fundamentals, both from airflow and lighting perspectives, and the integration of advanced technologies and design strategies into the prototype.
- Identifying and addressing crucial barriers, such as meeting industry standard test methods.
- Refinement of design based on feedback during the process.

The project's principal result is that the research team developed a prototype low-flow fume hood that successfully contains tracer gas, per the ASHRAE 11C fume hood test, at an airflow volume 70 percent lower than a conventional fume hood. LBNL's work on fume hoods also included the development of a new high performance fume hood lighting system that reduces energy used for lighting by nearly 50 percent. The new system utilizes a single T5 fluorescent lamp in lieu of two T12 lamps and, as a result, is more reliable and requires less maintenance. Tests indicate that the light produced is more evenly modulated across the task plane than the light produced by a T12 system.

Figure 2.2.1
LBNL's Berkeley Lab High-
Performance Fume Hood
(Lawrence Berkeley National Labs)



Fisher Hamilton's Concept 2000 Fume Hood
(Fisher Hamilton)



FISHER HAMILTON'S CONCEPT 2000 FUME HOOD

Fisher Hamilton's work on the EPICenter project involved both re-designing their Horizon Hood to reduce exhaust volumes and developing a new energy-efficient fume hood called the Concept 2000.

The Horizon hood was re-designed to reduce exhaust volumes by 50 percent. This entailed re-engineering the hood construction to accommodate a combination sash. The new sash configuration will provide full vertical height for normal operation (e.g., set-up mode) while

offering a "safety shield" for the operator. An alarm system monitors the sash position.

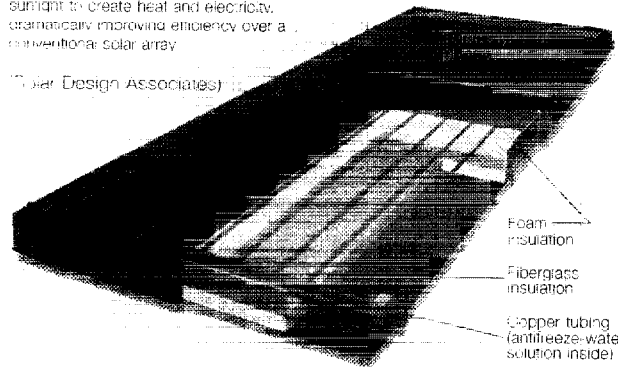
Fisher Hamilton is in the process of developing a next generation energy-efficient fume hood called Concept 2000. The fume hood is currently in the development stages and the MSU's prototype installation at the Safety and Risk Management facility is the first end-user test site. The Concept 2000 fume hood will enable the use of lower face velocities (60 FPM) and tempered air volumes without sacrificing capture and containment efficiencies in the set-up mode. This fume hood concept will also incorporate a higher sight line for observation of tall apparatus and distillation racks during the operation mode. A patented "Autosash" mechanism has been engineered to return the fume hood sash to the safe 18" operating opening. The sash, in this position, will act as a safety shield against potential explosions. Fisher Hamilton, who is currently developing a testing procedure and methodology based on ASHRAE 110 testing for containment and flow, will monitor MSU's prototype installation.

It is interesting to note that Fisher Hamilton attributes the MSU EPICenter project with raising their awareness of the potential for new, "greener" products in the laboratory equipment industry. They discuss the following results in their Technical Report:

- Development of high-efficiency fume hoods.
- Incorporation of a finishing system for both wood and steel products with near zero VOC emissions and minimization of hazardous waste disposal during the finishing process.
- Incorporation of "certified sustainable wood" products as a standard option. In August 2000, Fisher Hamilton was certified for chain of custody by SmartWood.
- Procurement of cold rolled sheet steel with a minimal recycled steel content of 20-25 percent.
- Incorporation of "blanket-wrap" product shipments as standard practice (to eliminate cardboard and wrapping products).
- Additionally, Fisher Hamilton is in the process of writing revised architectural specifications for their products to incorporate "Green Building Products" and "Environmentally Friendly" manufacturing processes.

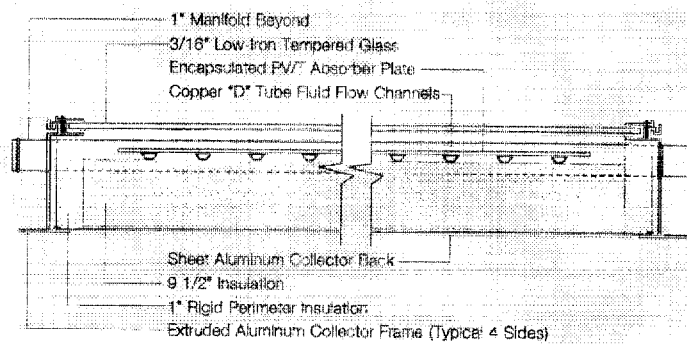
A new type of photovoltaic panel collects sunlight to create heat and electricity, dramatically improving efficiency over a conventional solar array.

(Solar Design Associates)



THE HYBRID INTEGRATED SOLAR COLLECTOR

The Pilot building was designed to showcase emerging new energy and thermal generating technologies that have been combined into a roof integrated product, Solar Design Associates' (SDA) hybrid integrated solar thermal collector. These photovoltaic panels, in addition to providing up to 20kw of power and a significant amount of domestic hot water, would also serve as the building's roof surface. As mentioned earlier, because the beta test could not be incorporated into the Pilot building, a hybrid, but not integrated version of the collector (called Phototherm) was installed at MSU's Safety and Risk Management Facility. SDA will monitor the electrical and thermal performance of the prototype to provide valuable feedback into the operation and efficiency of the combined collector.



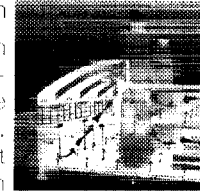
Hybrid Integrated Solar/Thermal Collector
(Solar Design Associates)

2.3

HARNESSING ENERGY FROM NATURE

Jason F. McLennan

Mounting evidence concerning the role of humans in natural ecosystems indicates that the world ecosystem cannot long endure a wide-scale replication of the resource-depleting patterns of recent Western growth. Indeed, the science of ecology is suggesting that many of our religiously held beliefs—like the belief in perpetual economic growth—are in fact colossal illusions.

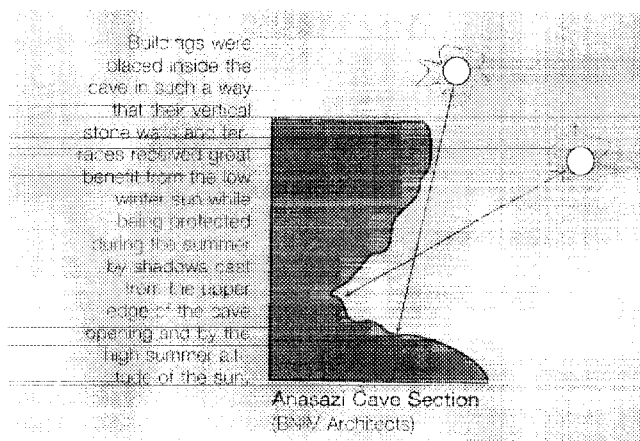


Timothy C. Wleskel



Throughout the development of the EPICenter project, energy use was recognized as the single largest impact category on the environment. Setting new standards for the use and generation of electricity was thus foremost on the team's list of goals for the project.

For thousands of years human society was at the mercy of the elements. Nevertheless, early societies devised clever ways to build buildings that harnessed those elements to temper the effects of climate. Buildings evolved in response to climate, local resources, and topography, changing form and composition as necessary to protect what was inside from the elements, while regulating temperature and humidity to the greatest extent possible. This in turn resulted in regionally distinct architecture that was both defined by and helped to shape culture. This evolution produced vernacular



forms that differed from locale to locale in a similar way that plants and animals differ from biome to biome (see "The Living Building"). Regardless of the climate or culture, all these buildings had one thing in common—they relied on "current solar income." In other words, they harnessed energy from nature that was currently in production such as wind, biomass or direct solar radiation. The result was buildings that had little environmental impact once they were built.





But Western society was never completely satisfied with a close relationship to nature and was quick to follow the ideas of individuals like Francis Bacon who sought "dominion over nature" using the scientific method. As early as the 17th century, we began to look for ways to put distance between the elements on the outside and activities held indoors, to be warm no matter how cold it was outside, or cool no matter how hot. The turning point came when we realized that energy was also available in "stored form" as coal (and later petroleum and natural gas) and could be collected and used for any purpose at any time. Unfortunately, in our haste to surge ahead with "progress" we lost the ability to discern between practices that were damaging to environmental health and those that were not.

Since then we have become a society addicted to energy use, a problem most visible in the design of modern cities and buildings. The history of architecture in the 20th century can be viewed as a history of buildings emulating machines and technology. The machine, such as the internal combustion engine, has been the symbol of progress and mankind's mastery over nature for the last hundred years. The machine has allowed us to achieve comfort in any climate, to traverse long distances in short amounts of time and has revolutionized everything from food production to the manufacture of clothing. It is not surprising that machines are the ultimate metaphor for the buildings of today. Le Corbusier, one of the 20th century's best known architects, even went so far as to say that, "houses were machines for living in."

As machines, our buildings also began to look more and more similar, regardless of culture or climate. With machines as metaphors, our buildings took on the characteristics of clinical assembly line productions. An office building in Singapore now looks the same as an office building in Manhattan and both share the same "perfect" climate controlled indoor environment. At the same time, the loss of regional difference began to undermine the uniqueness of place, removing us from understanding what local culture and climate have to offer.

Unfortunately, like the machines of our age, our buildings use energy and materials wantonly, depleting resources and using energy in ways that are beginning to alter the very climate that we all depend on. According to the US Green Building Council, buildings in the United States consume 30 percent of our total energy and 60 percent of our electricity while generating 2.5 pounds of solid waste per square foot of floor space for construction alone. Five billion gallons of water are used per day in buildings just to flush toilets! The root of the problem was our shortsighted belief that technology combined with a great deal of energy was the answer to any design problem.

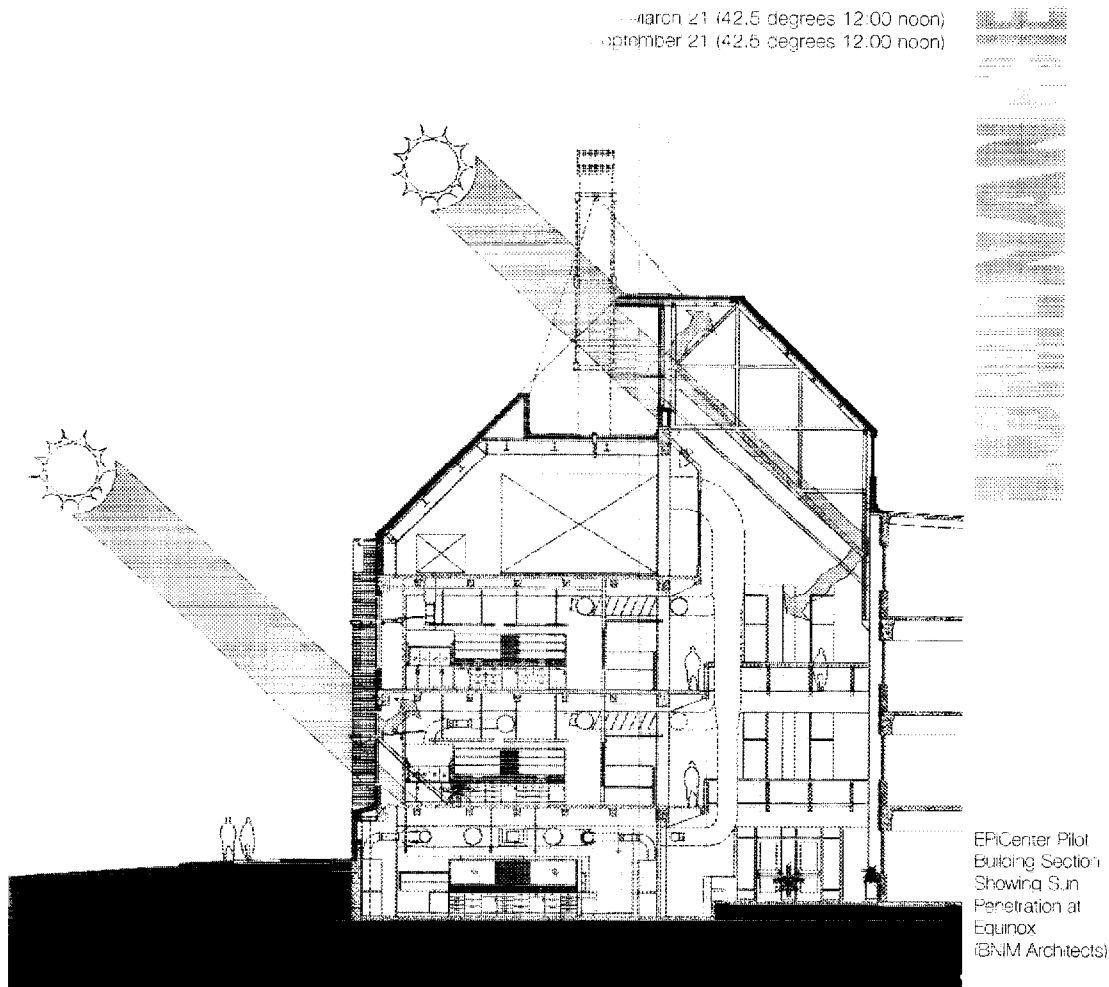
The design of the EPICenter project, like others in the green architecture movement, was a call to restore balance between the desire for modern comfort with the impacts that are now synonymous with it; to embrace appropriate technologies that use current solar income instead of drawing down nature's "capital"; to seek and implement age-old design solutions determined by culture and place.

In Montana, energy conservation was particularly important because of the state's extreme winter temperatures. Fortunately, Montana is also blessed with an almost ideal climate for the utilization of passive heating and cooling: low humidity and large diurnal temperature swings in the summer, as well as a frequently clear sky allowing solar gain in cold periods.

A challenge for the design team was to embrace these passive strategies in a laboratory building that required a great deal of conditioned air regardless of outside temperature. In a sense, the project team was given the most challenging building type possible in which to demonstrate green building techniques. In order to meet this challenge, the design team embraced the "Plus Ultra" methodology and holistic thinking process described earlier and assembled a world class Performance team to evaluate design strategies.

KEY SUSTAINABLE STRATEGIES ADOPTED FOR THE EPICenter INCLUDED:

DAYLIGHTING

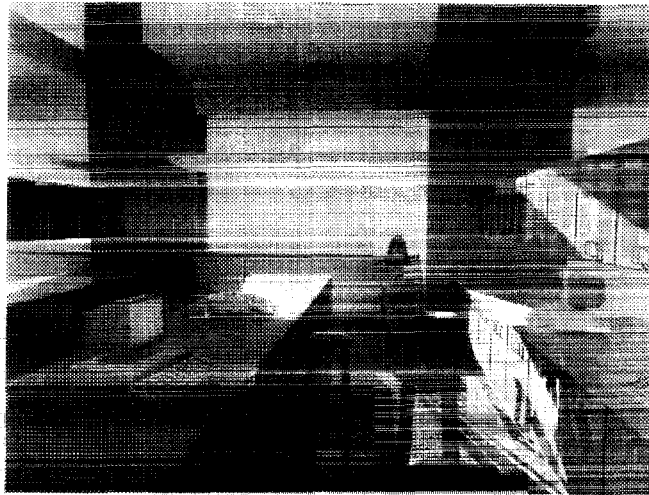


Daylight produces the most amount of light to the least amount of heat and properly designed can greatly reduce the amount of energy required to provide a quality luminous environment while reducing heat loads within the building. The design team spent a great deal of time studying the potential for daylight to be the major source of illuminance in all primary spaces during daytime hours. Daylighting was an integral part of each of the EPICenter schemes and, ultimately, the most detailed exploration was completed during the Pilot building phase of the project. From the outset, each of the EPICenter schemes was organized to allow for the maximum use of daylight. All schemes were elongated in the east/west direction to provide maximum exposure to south and north light. Light shelves and light redirecting technologies played an integral part of each of the designs. South facing windows above light shelves provide illumination deep into the laboratory spaces, while smaller windows below the light shell provide views and light at the perimeter. The atrium receives the majority of its daylight from a large 15-foot clerestory window facing south, with additional light from punched openings high on the north facing elevation.

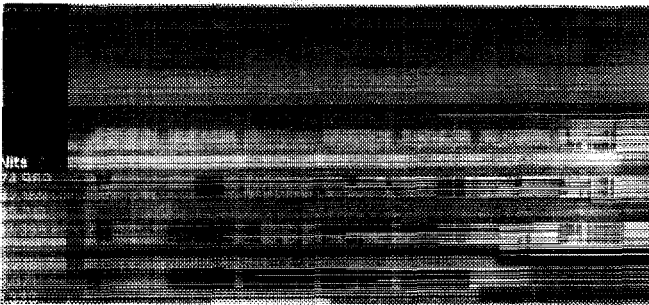
Daylighting
Model of
EPICenter Pilot
Building
Research Lab
(BNIM Architects)



InterScape Model
View of Pilot Building
Research Lab
John Wood



Radiance Diagram
View of Pilot Building
Interior Elevation of
James Hall
Lawrence Berkeley
National Laboratory

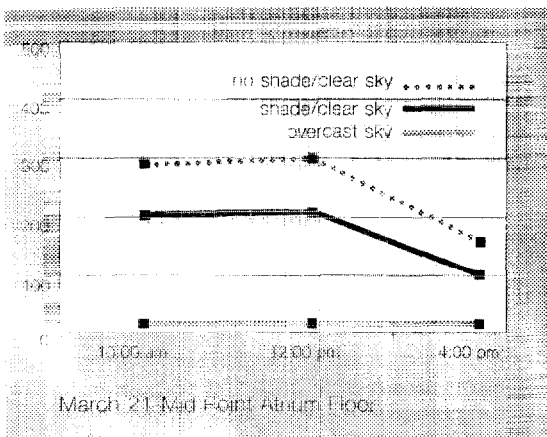


For most of the daylighting studies in the Pilot building, the team used physical models for both qualitative and quantitative testing. A T-10 illuminance meter was used to take footcandle readings within the modeled spaces to determine where in the spaces, and at what time of the year, adequate daylight levels were reached. The team used the daylight model to modify the design of light shelves within the laboratory spaces and to provide the necessary information needed by Nancy Clanton, the team's lighting design-

er, to design the electric lighting in the labs and atrium. The electric lighting and daylighting schemes were a heavily coordinated effort.

Glazing was also a major consideration and the design team selected glazing with different properties depending on the orientation and location of the openings in the building. The goal was to choose the best glass for each location and to balance the need to control glare, permit visible light, and control heat loss and heat gain. In the atrium space, where comfort conditions will rely more heavily on the performance of the envelope, triple-pane super-insulating glass was chosen, although the properties of this glass varied with orientation. In general, west and east facing glass relied on increased glare control with a reduction in visible light transmittance, whereas visible light transmittance was maximized in south and north locations where the illuminance levels and heat gain could more easily be controlled. Glare was controlled in the south locations through the use of light shelves and shading devices.

Daylighting Results Chart
BNIM Architects



To further study daylighting, the core design team enlisted the aid of several design professionals to help test alternative solutions that would balance illuminance with glare concerns. Professor Tom Wood of Montana State University spent a week during the schematic design phase of the Pilot building in Kansas City to help the design team explore various design options. Professor Wood was particularly helpful in convincing the team to move away from skylights in the atrium space (which produced a lack of control for thermal gains) to the final solution that involved clerestory windows in which

thermal gains could more easily be controlled. Professor Wood used Lightscape, a computer modeling tool, and Visual DOE in his work at BNIM.

Eleanor Lee of LBNL also played a role in the daylighting design of the Pilot building and served as a consultant providing advice and confirmation of the glazing selection and daylight modeling. The LBNL group was instrumental in convincing the team to increase the physical area of the clerestory window in the atrium in order to provide more illuminance.

The team used Radiance (the powerful daylight modeling tool developed by LBNL) to test the illuminance levels within the atrium at various points throughout the year. Unfortunately, the light levels predicted by Radiance in the atrium were significantly lower than what was shown in the physical model, a discrepancy that was never fully resolved due to time constraints at the end of the project.

Greg Franta of the ENSAR Group also provided advice and design assistance to the team on glazing selection and daylight modeling. Franta was originally involved in Phase I of the project and then on the Pilot building. On the Pilot building, Franta assisted the group in its first physical modeling tests and confirmed that the modeling procedures used by BNIM were consistent with his techniques. Franta also confirmed that the glazing selected by the design team was the best choice in each location and helped the design team refine the design of the light shell in the laboratories.

All in all, daylighting design played a significant role in shaping the building design at each phase of the project and in the team's efforts to lower the operating impact and the energy use of the design while contributing to a quality environment.

SELECTING LIGHTING

The design team's goal to produce a quality Plus Ultra environment started with daylighting design and continued with the integration of super efficient, high quality electric lighting and controls. Nancy Clanton, of Clanton and Associates, was involved in all stages of the project and provided the design of the lighting systems for the Pilot building that included super efficient fixtures with T-5 fluorescent lamps and daylighting controls. Clanton's design approach centered on several principles (see Technical Report):

- Use quality daylighting as the primary lighting source instead of relying solely on electric lighting.
- Provide direct/indirect electric lighting for comfortable working environments in the labs and classrooms instead of relying on direct lighting only.
- Increase lighting levels with task lighting for special tasks instead of increasing the ambient lighting levels.
- Light surfaces instead of volumes in the general circulation area for a more comfortable atmosphere.
- Light specific areas and events individually with regard to their use and character instead of providing a uniformly lit environment.
- Provide individual lighting control to the classrooms and laboratories for greater control and savings potential.
- Provide lighting controls to turn off lights when spaces are unoccupied for greater savings.

TASK LIGHTING



The successful integration and performance of the lighting systems to meet the goal of high quality energy-efficient lighting with increased visual comfort also allowed the mechanical engineers to reduce the cooling loads and downsize the cooling system.

ENERGY-EFFICIENT ENVELOPE

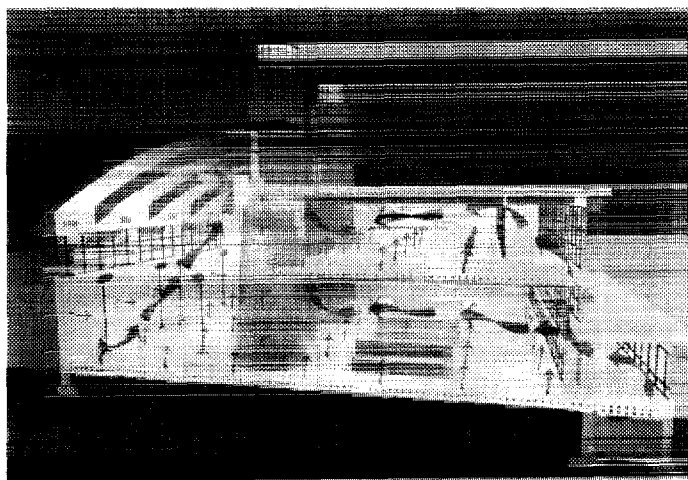
BNIM Architects was responsible for creating the most energy-efficient envelope possible within the Pilot building budget. Initially the team looked to alternative building materials with high R-values to provide the thermal protection such as strawbale construction. However, due to code restrictions when the project became a research laboratory with a firm move-in date, the team had to comply with existing building codes and rely on traditional building materials. The team spent a great deal of effort to minimize thermal bridging in the project with the use of exterior rigid insulation and careful detailing. High performance windows were selected to keep heat loss in the winter to a minimum. Great care was taken to select the appropriate glazing, tuned to its location and orientation to provide the right balance of heat gain or loss and daylight transmittance. For example, in the atrium, which relied more heavily on passive strategies for heating and cooling, triple-pane windows with low-e coatings were selected.

As with any energy efficient envelope, great care needed to be taken to ensure that problems with moisture were not created as the building became more air-tight. Greg Sheldon of BNIM investigated moisture migration through the envelope with help from Joe Lstiburek to mitigate concerns of trapping moisture and causing mold growth or degradation within the exterior walls (see Technical Report). In the end, a tight envelope was designed with high R-values for the roof, walls and basement.

PASSIVE HEATING AND COOLING EFFORTS

Since the Gallatin Valley, in which Bozeman sits, is ideal for most passive strategies it was always a goal to use passive heating and cooling strategies to provide comfort. The original National ReSource Center project was designed to be heated passively using direct solar gain strategies and cooled passively by capitalizing on the day/night diurnal effect and stack ventilation. Short-Ford Associates from London were on the original project team to help with passive cooling efforts as well as Doug Balcomb from the National Renewable Energy Lab (NREL) for passive heating.

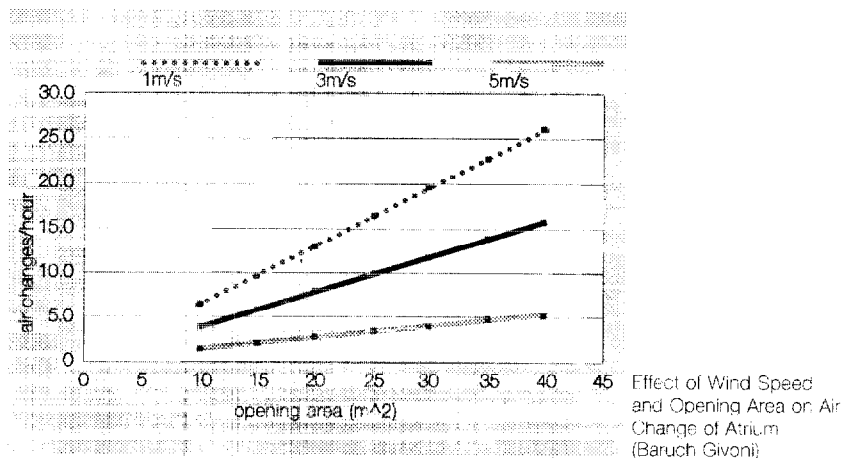
National ReSource Center Building
Section illustrating Passive Cooling
(BNIM Architects)



As the project shifted sites and focus to a mechanically intensive laboratory building, the reliance on passive systems was diminished but not forgotten. The Pilot building was designed to embrace winter sun for "free heat" in all areas of the building, while rejecting summer heat. South facing overhangs and shading devices were integral parts of the building design.

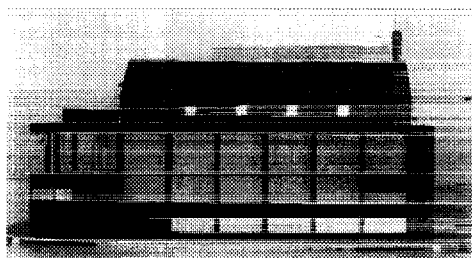
The Pilot building was also designed so that the areas that did not need mechanical intervention and high ventilation rates were grouped together in the atrium. The large atrium space contained a collection of student study spaces that were kept comfortable in summer months through passive cooling. To help design the passive system, the team enlisted Baruch Givoni, professor emeritus from UCLA and author of several books on passive cooling. Together Baruch and the Performance team designed the passive cooling system taking into account the size, density and location of thermal mass, availability and direction of wind, and the amount of internal heat gains and external temperature during a heat wave.

The passive cooling strategy relied on night ventilation strategies as temperatures at night drop by as much as 30 degrees Fahrenheit (or even more during heat wave temperatures). During hot weather, the building would remain in "closed" mode during the daytime and would rely on the high amount of thermal mass located within the building to keep temperatures cool until nighttime. While initially the design team focused on stack ventilation, this approach was changed to cross ventilation after Givoni compared the effectiveness in the region and determined that cross ventilation purged the building of heat most effectively. The design team then worked with Givoni to design, size, and locate mechanically operated openings in the east and west facades of the atrium.



Effect of Wind Speed and Opening Area on Air Change of Atrium (Baruch Givoni)

The successful design and location of the openings were confirmed by wind tunnel testing of a physical model of the atrium using flow visualization techniques. The design team utilized a helium bubble generator and recreated design conditions in a wind tunnel at the University of Kansas to test and observe wind flow within the building. Helium bubble generators produce neutrally buoyant bubbles that can be used to observe air flow patterns around or through a building. Aeronautical engineers helped the team analyze the wind flow patterns within the space and determined that the inlet and outlet locations successfully introduced air so that all internal thermal mass would come in contact with the air stream necessary for night ventilation. The Performance team also developed a protocol for when the system would operate, to protect the atrium from excessive wind, rain, and overheating (see Technical Report).

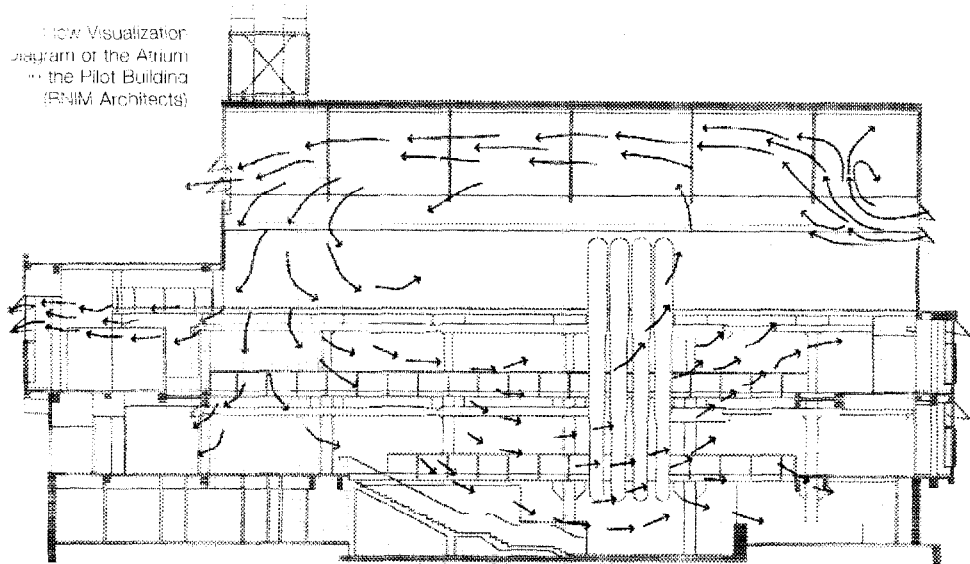


Flow Visualization Model of the Pilot Building Atrium (BNIM Architects)



Flow Visualization Equipment (BNIM Architects)

Flow Visualization
Diagram of the Atrium
in the Pilot Building
(BNIM Architects)



INTEGRATED MECHANICAL SYSTEM

Perhaps the most important area for the design team to make inroads into efficiency and performance was in the design of the mechanical system that served the Pilot building. As laboratories are typically huge consumers of energy, designing an integrated mechanical system that reconsidered traditional assumptions and components provided the greatest area for improvement. The problem was made more significant due to the harsh winters in Bozeman and the large amount of energy required to pre-heat the building supply air. The Performance team played a significant role in the final development of the mechanical system, providing input at multiple points along the way (see "A 'Plus Ultra' Design Process"). The main designers of the mechanical system were Shawn Murray of CTA Architects/Engineers and Peter Humsey and Ron Perkins of Supersymmetry.

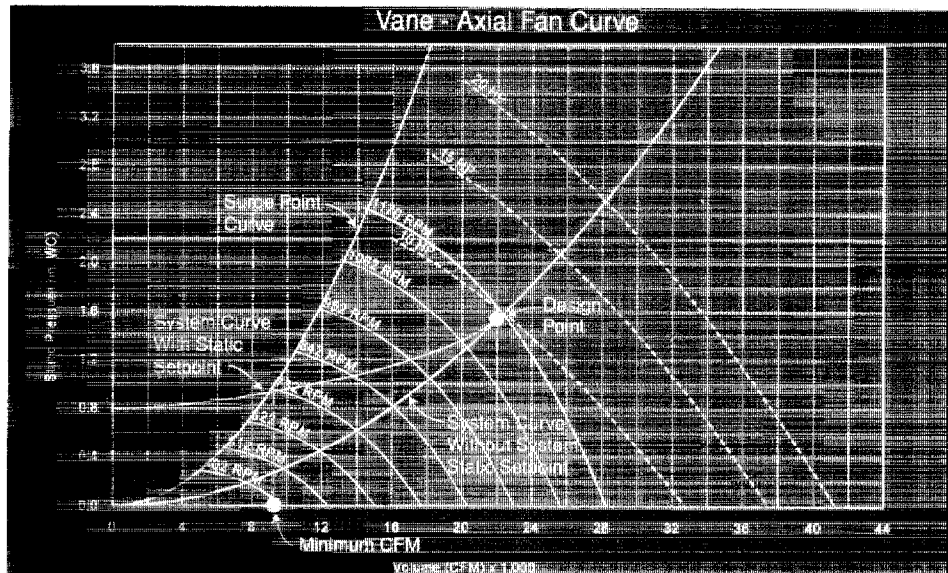
The team started with the fume hoods, sought passive alternatives to precondition makeup air, set stringent pressure-drop goals, and designed a system to fit those goals. This is contrary to standard practice in which designs are completed and the pressure-drop is merely determined as a result. Minimizing the pressure-drop across the system reduces the amount of energy needed to provide the same unit of comfort, greatly reducing operating costs and energy use. The team also assembled a unique collection of standard components to produce the mechanical system rather than "packaged" units from fewer sources. The goal was always to select the most efficient equipment for each particular function, understanding the power of the overall efficiency when combined.

The team continued to "buck" standard engineering practice, which relies heavily on large safety factors that often combine to produce greatly oversized systems. As the authors of *Natural Capitalism* state, there "is no liability for inefficiency—only for insufficiency." Instead the team relied on the principle of "rightsizing," which relies on "measured" data of equipment capacity and size needed rather than rules of thumb. Rightsizing not only saves money in reduced equipment size, but also improves efficiency as most mechanical equipment runs more efficiently when it is operating nearer to capacity. The team also took seriously the role of diversity in fume hood usage, sizing the system to accommodate the amount of hoods that should be in use at any given time (the hoods go into alarm when too many hoods have open sashes). For a more accurate understanding of fume hood diversity the engineers spent time with the building users to learn what diversity was acceptable.

SOLAR INCOME

The project was successful in helping both Lawrence Berkeley National Labs and Fisher Hamilton develop highly efficient fume hoods that greatly reduce the amount of air needed while maintaining or increasing user safety. Early testing shows energy reductions of between 30 and 60 percent while maintaining containment, which could help redefine the industry (see "Technology Transfer and Selection").

The team was able to eliminate system re-heat within the building and conventional mechanical refrigeration, and replace them with more efficient and pleasant radiant heating, and evaporative and direct ground water cooling. The Performance team managed to meet their goals of producing what they believe is the most efficient laboratory mechanical system yet designed.



Vane-Axial Fan Curve
(CTA Architects Engineers)

PLUS ULTRA COMMISSIONING AND MONITORING

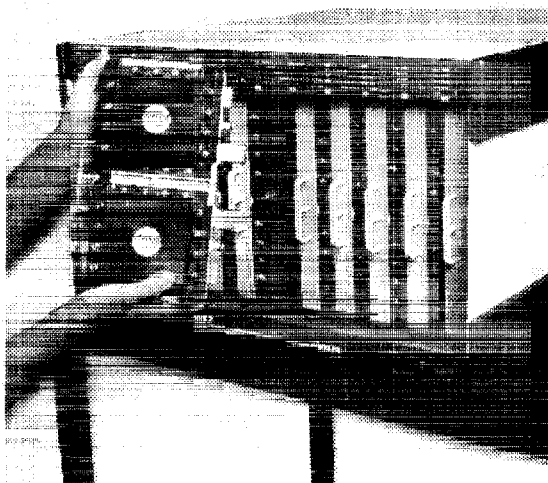
To ensure that the Pilot building would perform as designed, the Performance team re-examined the commissioning process to measure and track building performance over time. This new commissioning process went well beyond making sure that equipment installed is working correctly with "snapshot" component specific data. The Plus Ultra commissioning process allows for continuous commissioning by performing tests and balancing of all systems at all load conditions continuously over the life of the system. In addition, the data received is continually saved for future analysis.

CURRENT SOLAR INCOME

Once the amount of energy needed for the Pilot building had been made as small as possible, the Performance team looked to include technologies that could provide 100 percent of the remaining energy using "current solar and wind income." The NIST grant supported the development of a hybrid integrated solar collector developed by Solar Design Associates in conjunction with Sunearth and Unisolar for the south facing "roof" of the Pilot building providing both hot water and electricity (see "Technology Transfer and Selection"). This 20 kw solar array is capable of providing between 10-20 percent of the building's electricity needs. A beta demonstration of this new technology was installed at MSU's Safety and Risk Management Facility in September 2000.

The team also investigated the use of fuel cells for electricity generation and during the design phases of the Pilot building MSU discussed a potential industry partnership with AvistaLabs. AvistaLabs is currently in the early stages of producing a commercially viable fuel cell for building power, and it is planned that the Pilot building will be a demonstration site for a beta version of this new technology.

Proton Exchange Membrane (PEM) Fuel Cell (AvistaLabs)



In order to complete its goal of providing 100 percent of electricity from renewable energy sources, the team initiated discussions with Gordon Britton, who owns a local wind farm, to purchase the remaining 80-90 percent of the Pilot building's energy

needs. An agreement was reached to seek a partnership between Britton, MSU and Montana Power (who would provide transmission and fly ash as a byproduct of their coal-fired plants) for the Pilot building (see "The Future of Material Selection"). These steps would ensure that the building operated using 100 percent current solar and wind income—a major step toward a future of laboratory buildings when comfort and performance are achieved with minimal operating impact.

THE RESULTS

The results of the design and Performance team's efforts to reduce the operating impact of the Pilot building are impressive. A DOE-2 simulation of the building design illustrated how this project may in fact be the most energy-efficient lab building ever designed. John Weale of Supersymmetry created the DOE-2 model to evaluate the predicted energy use of the building as compared to a conventional design. The Efficiency Metric Comparison table (figure 2.3.1) shows that the building uses roughly a third of the energy of a typical lab building in that region. These results are even more interesting as the DOE run is dissected further, as figure 2.3.2 illustrates, which shows that the decision to passively cool the atrium, in addition to the building's other energy efficient features, accounts for much of the reduction. Figure 2.3.3 shows the breakdown of energy consumption by category for the Pilot building versus a typical lab. This diagram illustrates the greatly reduced impact from ventilation air and cooling which typically are the biggest energy consumers in the lab.

The results of this reduced energy demand include significant reductions in pollution generated over the life of the building and money saved by the university. Based on typical utility rates in Bozeman, the Pilot building design would save approximately \$120,000 per year over a traditional design. Over a 20-year period this would result in a \$2.4 million savings, assuming that utility rates don't rise (a conservative assumption). The estimated first cost increase over conventional mechanical systems was approximately \$350,000 representing only a 2.9 year payback!

This is not the complete economic story however, as part of the mechanical systems savings are attributable to better lighting systems and envelope construction as well as to the low pressure drop HVAC system. The building construction estimate of \$6.8 million breaks down into a cost of \$220 per square foot, which compares favorably to the current standard of \$200 per square foot for university chemistry buildings, resulting in an overall "green premium" of

Fig. 2.3.1
Efficiency Metric
Comparison
(Supersymmetry)

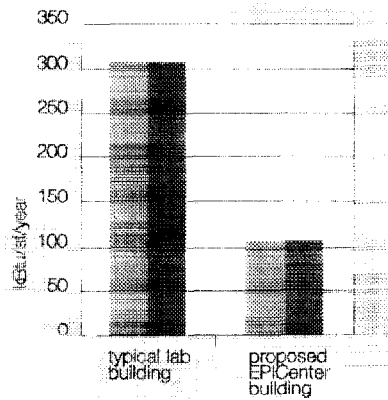


Fig. 2.3.2
Lab/Atrium
Comparison
(Supersymmetry)

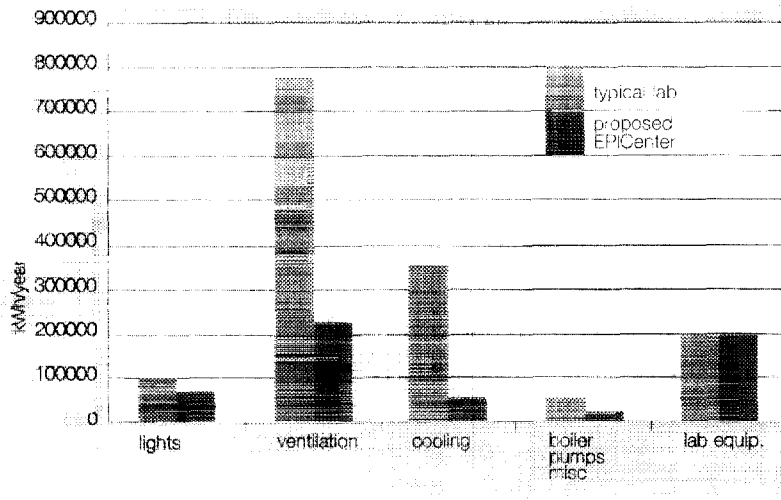
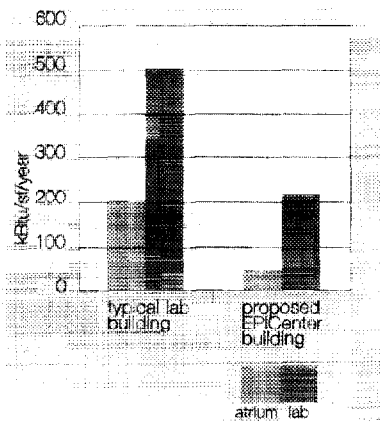
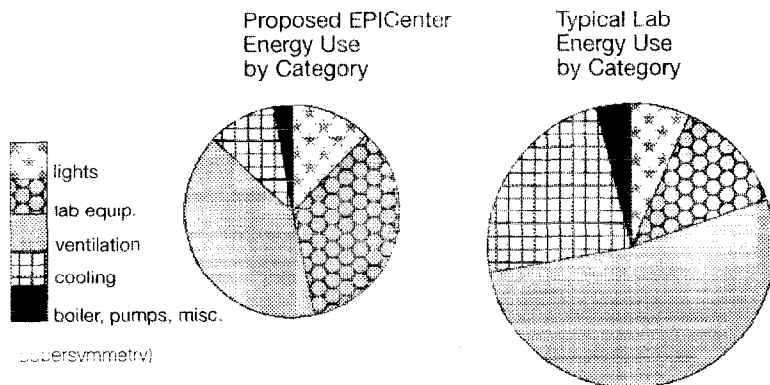


Figure 2.3.3
Comparison of Energy
Consumption by
Category
(Supersymmetry)



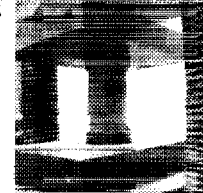
\$628,000 in first costs. Based on the operating savings shown above, this will still result in a payback of only five years, for all of the "green" features including those that don't impact energy. These savings do not take into account other factors that will lower the payback time and improve the buildings economic performance, such as reduced maintenance costs for longer lasting equipment and lighting, and gains in productivity that could be expected due to the project's improved human comfort features (see "Improving Human Health and Productivity"). These achievements do not even include the gains that would have been made if the advanced fume hoods developed for the project were used exclusively. Nor does it account for high efficiency lab equipment, which was not included in the project budget. If the super-efficient fume hoods developed by Lawrence Berkeley National Labs and Fisher Hamilton were used on the project, in conjunction with energy-efficient lab equipment, the results would have been staggering. In essence, the design team proved, thanks to the NIST funding, that it is possible to design a laboratory building that uses only 15-20 percent of the energy of a conventional laboratory building while meeting tight budget requirements.

CONCLUSIONS

2.4

THE FUTURE OF MATERIAL SELECTION

Jason F. McLennan + Sylvatica + CMPBS



Everything we need, could want, could dream of is here on earth in some form, but the tragedy is we are destroying the unknown potential of dreams to come every day.

Janine Benyus, *Biomimicry*

From the very beginning of the MSU EPICenter project, material selection was one of the most important aspects. The design team recognized that if they were to be successful in changing the way buildings are designed, built and operated, then they had to start by examining the very things that make up our buildings: brick, stone, concrete, glass and wood. Additionally, the team realized that their responsibilities go beyond how these materials are put together on a construction site, and that they needed to broaden their understanding of materials to also include the following issues:

- how they were harvested
- how they arrived to the site
- how they were manufactured
- how they would be disposed of when the building's useful life was over

As part of the "Plus Ultra" mantra that organized and shaped the project, the design team identified the current state of the art with regard to sustainable materials and selection methodologies, and worked to identify ways to improve upon the status quo in the areas of resource and energy efficiency, human health, and the impact of material selection on the regional economy.

THE STATE OF MATERIAL SELECTION

Before the Industrial Revolution, the materials that shaped our buildings came from within a small radius of the construction site, often a distance of no more than a few dozen miles depending on the material and its mass. Buildings during this epoch could be said to be "born from place," shaped locally, and tied to culture and climate. But as our society invented more and more ingenious methods for carrying people and goods over large distances, the circle began to widen and materials once seen only near their place of origin began to spread farther and farther outward.

Today it is surprising to find any buildings built primarily from materials within a small radius of the construction site. Increasingly, building materials arrive at the construction site from other countries and continents. As can be imagined, the environmental impact of shipping materials over great distances is immense. The heavier and more massive the material, the greater the amount of fuel consumed and pollution generated. Compounding the problem is the fact that building materials have also become more complex over the last one hundred years. Where building products were once fabricated from simple raw materials that had been altered in only small ways from their original form (cutting and dressing stone for example), now materials in common use are being made from hundreds of different chemicals and goods, each from different parts of the globe.

IMPROVE

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The Future of Material Selection
Jason F. McLennan + Sylvatica + CMPBS

Until very recently many architects and design professionals saw these trends as only a positive thing. Imagine being able to install any material in your building, from anywhere in the world! Imagine the design possibilities this opened up! Building materials could now be chosen based on three simple criteria: how the product looked, how it performed its intended function, and how much it cost. Architects were no longer hampered by what was available locally. The problem was that a fourth question was never asked in the selection process: Is it a responsible choice? This one question raised a host of others. How much waste was generated to produce a unit of the material? (Most materials in use are the result of almost ten times their weight in waste.) Just as the simple stroke of the architect's pencil had represented a commitment in stone, steel, and concrete, it was now understood that it also represented a commitment to ozone-depleting chemicals, ground water pollution, global warming, and acid rain. These are the types of questions absent for so long from the material specification process...

- Should materials be selected that look good and are cost effective (when defined by traditional economics) but are the cause of serious water and air pollution with by-products known to cause cancer?
- Should materials be selected that have been made from ingredients from all over the globe when there are better local alternatives?
- Should materials be used that cannot be recycled or broken down under natural processes for thousands of years?
- What is the impact of material selection on local economies when resources are viewed only as valueless inputs—valueless, that is, until they have been converted into useful products?

Unfortunately, the environmental problems associated with the current methods for material selection do not stop with the energy it takes to transform and transport materials. Increasingly, designers are realizing that the materials they specify also have a significant effect on human health. More chemicals are being used in the manufacture of building materials than ever before. These materials, combined with poor ventilation and cleaning methods, are creating sick buildings and poor indoor air quality.

The EPICenter project emerged as part of a larger movement based on the belief that it is time to consider whether a building and its materials were "responsible choices"—a key issue in the "green" architecture movement. When the EPICenter project began in 1993 there was a serious shortage of information related to the environmental impact of the materials architects specify for their buildings. In addition, the knowledge of what made a material "green" was lacking. Since the start of the project, as in many other disciplines, the amount of information available in this particular area has exploded. Information does not knowledge make, however, and architects are now confronted with trying to stay current on ever-changing products and their impacts while wading through a sea of misinformation and biased product literature. Architects working within limited budgets are now also faced with the challenge of prioritizing which materials will do the least harm. Many so-called "green" products are overpriced because they are viewed as expensive specialty items. The process of identifying the most appropriate materials for a building, not to mention taking into account all four questions set forth above, is a daunting one and often leads to poor choices.

Based on this reality, the design team set some specific goals for material selection on the EPICenter project. These goals have subsequently helped to change the industry's understanding of the issues related to material selection.

GOALS FOR MATERIAL SELECTION ON THE MSU EPICenter PROJECT

- Recognize the value in regionality and take responsibility for asking the previously unasked question: was it harvested and made responsibly?
- Support the development of new materials that are less harmful to the environment.
- Develop new ways of selecting materials that take into account all impacts in all stages of its life.
- Examine the impact of material selection on human health.
- Determine the impact of material selection on local economic vitality.
- Help designers prioritize their environmental material selection and develop tools to do so.
- Expand the material selection criteria base to include: impact on indoor and ambient air quality, energy and resource efficiency, biodiversity, culture and economy, and whether the material is durable, recyclable, re-useable, biodegradable, non-toxic, and free of mutagens and endocrine disruptors.

At the initial Phase 1 goal setting charrette, a 1990 quote from Alvin Toffler's *Power Shift* was identified as a guiding principle:

"The only reason we now ship raw materials like bauxite or nickel or copper across the planet is that we lack the knowledge to convert local materials into usable substitutes. Once we acquire that know how, further drastic savings in transportation will result. In short, knowledge is a substitute for both resources and shipping."

One of the design team's first decisions was to reject the notion that materials should be brought from all over the world. We therefore began by drawing a 300-mile radius around the project site.

Within this 300-mile radius the design team proposed to capture 90 percent of all materials by weight used in the building. The team realized that some materials essential to high performance were currently not available within that radius but that a great deal could and should be specified from the local economy. In place of materials from all over the globe the team substituted intelligence in the form of scientists, building ecologists, engineers, and architects from all over the planet, understanding that ideas can be transported thousands of miles using modern communications with little or no environmental impact. This collective intelligence, the team believed, would allow the NIST grant to develop and fund better performing materials and material selection methodologies. This concept as simple as it sounds, was a new one to the building industry and quickly adopted by the "green" architecture movement as a paramount strategy for sustainable building. The simple radius diagram shown in figure 2.4.1 began to appear in books and in magazine articles all over the country. Most significant was the US Green Building Council's decision to use the concept as one of its "points" in its LEED (Leadership in Energy and Environmental Design) rating system that measures the environmental performance of buildings.

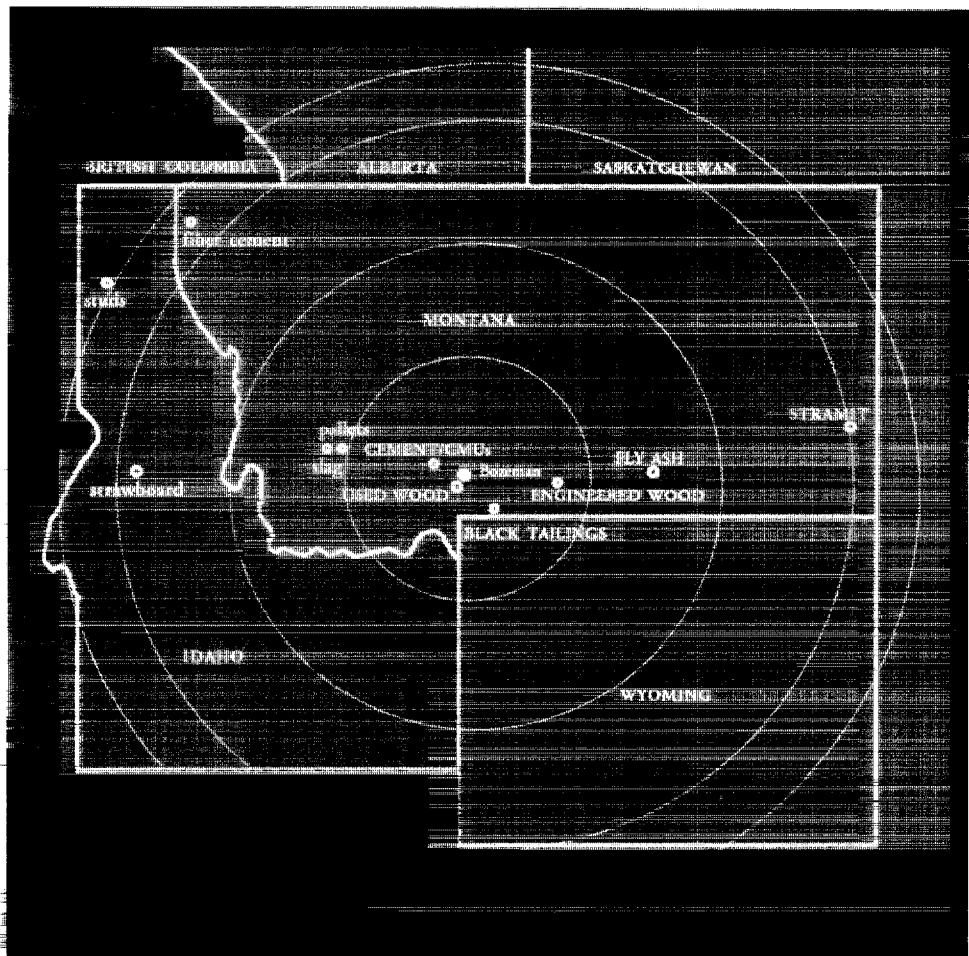


Figure 2.4.1
Material Radius
CMM Architects

Within the selected radius, the team then worked to create new building materials with small environmental impact by using resources from the local waste stream. The team was successful on many fronts.

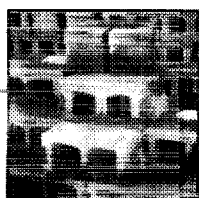
The first success was in developing a new concrete masonry unit using waste fly ash from the Corlette energy generation plant in Billings as a binder and mine tailings from the local Mineral Hill mines as aggregate. These materials, both from the local industrial waste stream, significantly reduced the amount of Portland cement and virgin aggregate normally needed to make the product. The new product also reduced the amount of waste locally while increasing the potential of the local economy to produce new products. Fly ash is a by-product of coal combustion and is being used increasingly as a substitute for Portland cement in concrete mixes. The MSU EPICenter project was important for raising the awareness and acceptability of using fly ash in concrete mixes. The environmental impact from Portland cement production worldwide is staggering (most notably CO₂ production) and this program proved that it was possible to create the same products with less environmental impact. Jerry Stephens, a civil engineer from MSU, was instrumental in testing the performance of these new materials. In addition, the lessons learned from this powerful example of industrial ecology were transferable to other regions of the United States. Industrial ecology is now

a burgeoning field worldwide, based on the notion that in nature there is no such thing as waste (waste = food). Similarly, there should be no such thing as industrial waste because each by-product from an industrial process should in some form be useful to another industry. Industrial ecology focuses on grouping industries together that have synergistic benefits, thereby reducing or eliminating "pollution" while maximizing efficiency.

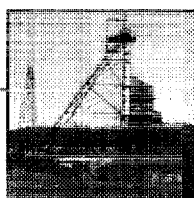
The EPICenter project proved that it is possible to help industrial ecology efforts get off the ground even on the scale of a single project by providing an instant market and testing grounds for newly developed products. The Phase 1 project, then called the National ReSource Center, took this concept even further and included spaces for the development and testing of new regional materials. While the National ReSource Center concept was not fully developed and the focus of the project shifted over time, the power of the original concept remains strong. There remains a demand for regional facilities located strategically around the country that can provide the resources and space necessary for companies to explore and test new materials.



fly ash



concrete masonry
unit manufacturer

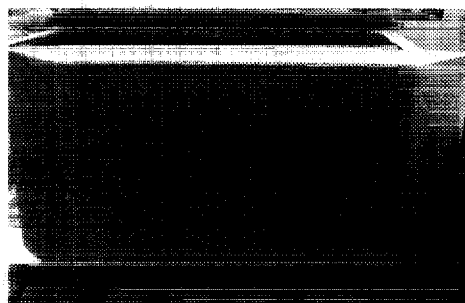


mine tailings

NEW REGIONAL MATERIALS

The efforts of the project team to create new lower-impact materials from the waste stream of Montana while increasing the potential for economic development did not stop with the development of the fly ash concrete blocks. The project funded the development of several other new products and processes including:

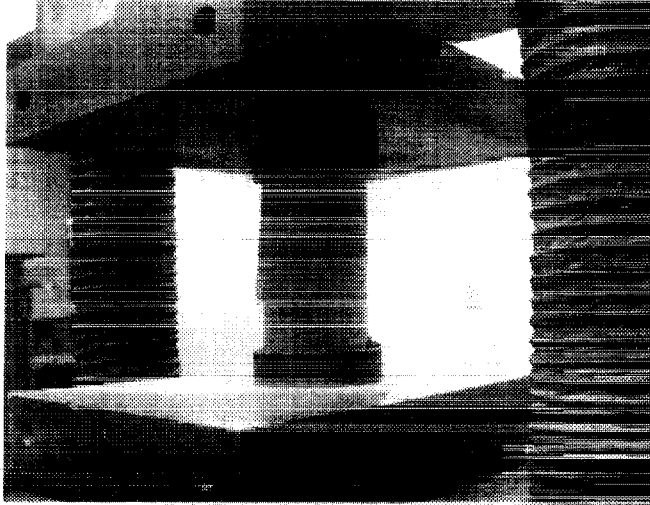
✶ **Fly Ash Composite Stone.** The project awarded a research grant to a small company from Three Forks, Montana, called Headwaters Composites to develop a new fly ash composite stone product that may be used for building cladding. This product uses 100 percent fly ash in lieu of Portland cement and recycled glass from the Montana waste stream instead of traditional aggregate. The result is an extremely strong and attractive product designed to be showcased in the EPICenter Pilot building. Headwaters plans to market the product commercially in 2001 and is also considering the idea of selling ready mix "bags" of the product for on-site use. Early testing suggests that the material exceeds the performance of conventional Portland cement products in several categories, most noticeably in its compressive strength which measures close to 10,000 psi. This has been a highly successful example of how the NIST grant supported the local Montana economy while minimizing environmental impact (see Technical Report).



Fly Ash Composite Stone
(BNM Architects)



Fly Ash Concrete
(Headwaters Composite)



Fly Ash Concrete. Working with Jerry Stephens, the team continued the ideas first introduced with the concrete block project to develop ideal mixes for creating poured-in-place concrete walls that use fly ash as a binder instead of Portland cement. It is planned to demonstrate this new process in the Pilot building. Similar to the Headwaters product, early testing showed very promising results in all categories of testing (see Technical Report).

Cast Earth. The team solicited the help of a building pioneer from Prescott, Arizona, Michael Frerking, to do further tests on a material that he and a chemist developed and were using for residential construction in Arizona. The material, similar to the fly ash concrete, uses no Portland cement but instead uses calcified gypsum as a binder. Like fly ash, gypsum is a waste product from industrial production but can also be manufactured. Test results showed a material that had good strength, albeit considerably weaker than traditional concrete. This product is very promising in many applications where high strength concrete is not needed and gypsum can be found in the region.

Originally the team was intrigued with the idea of using the excavated earth from the site in the new walls for the Pilot building but found that the soil content contained too much clay. In addition, "waste" gypsum was not found within an acceptable radius of the building site. Because of this the team decided not to include cast earth in the pilot building design.

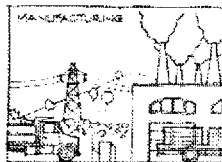
Stress Wave Analysis. The project funded research to determine if stress-wave analysis could be used on standing timber to non-destructively predict the quality of the lumber that could be harvested. Stress-wave analysis is a process currently used by the industry to determine the quality of wood once it has been harvested or to determine if there is internal decay on existing structures. Researchers at the University of Idaho's Department of Forest Products teamed with Boise Cascade to develop techniques for analyzing the quality of timber prior to cutting the trees down using stress-wave analysis. Early test results suggest that the process is very promising for the wood products industry to reduce waste and improve the optimization of timber resources.

LIFE-CYCLE ANALYSIS

While creating new materials from the Montana waste stream was a significant component of the team's efforts on materials, perhaps even more important were the efforts to develop a tool that could help architects understand the true impact of their material choices, as well as prioritize and evaluate alternatives. To do this the team realized that it needed to take a scientific approach to material selection and understand all aspects of a material's life cycle. This process is known as life-cycle analysis or life-cycle assessment (LCA) and it acknowledges that each phase of a material's life is responsible for a certain amount of pollution and energy consumption.

LIFE-CYCLE ANALYSIS

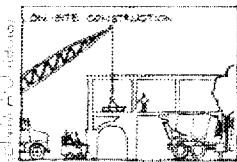
Life-cycle analysis consists of the following four phases:



"UPSTREAM"

Resource Extraction and Manufacturing

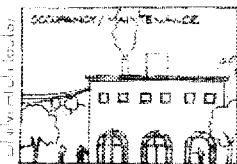
The upstream phase refers to impacts caused by the manufacture of the material and all its sub-ingredients prior to construction, including the material's transportation from its point of origin. The upstream phase is sometimes referred to as the embodied energy phase but in fact it deals with issues beyond energy use. The upstream phase is usually the most misunderstood phase of life-cycle analysis because modern building materials often have an incredibly complex story with many tiers of chemicals and raw materials from all corners of the earth.



"DIRECT"

On-Site Construction

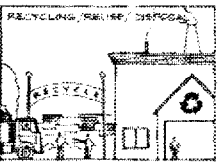
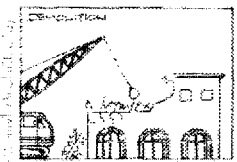
The direct phase refers to impacts caused by the construction of the building, including the final transportation of the material to the construction site, equipment and power used in construction, and all site impacts. This is usually the smallest impact phase but one in which architects can have a great deal of influence. A surprising amount of energy is used during construction for generators and temporary construction processes. Also significant at this stage are efforts to handle site waste management. It is important to note that careful ordering procedures and specification language can go a long way to reducing the impact of this phase.



"DOWNSTREAM"

Occupancy/Maintenance

The downstream phase refers to impacts caused during the operating life of the building, otherwise known as the usage phase. This phase is generally the most important phase of the life cycle relative to environmental impact, in terms of the amount of energy required to create a typical building, it often takes 10 to 15 times that amount to heat, cool, light, and maintain the same facility over the course of its operating life. This fact is responsible for the principle of operating energy taking precedence over embodied energy. However, as our buildings become more and more efficient, the proportional impact of the downstream phase becomes smaller. Indoor air quality issues also play an important role in this phase.



"POST-USAGE"

Demolition and Recycling/Reuse/Disposal

The post-usage phase refers to impacts created after the building's useful life is over, including the demolition of the building, and the reuse, recycling, or disposal of its materials. Most buildings today contain few materials that can be salvaged or recycled, or, if they do, they are not put together in such a way as to facilitate re-use or recycling.

The EPICenter project was one of the first projects in the US to take a holistic approach to material selection. Early on in the process the core team used local experts on materials (Steve Loken and Rod Miner) but in the end focused its work with the Center for Maximum Potential Building Systems (CMPBS) in Austin and Sylvatica in Boston. Together with BNIM this team developed a new tool called Baseline Green for material selection.

BASILINE GREEN

BASILINE GREEN

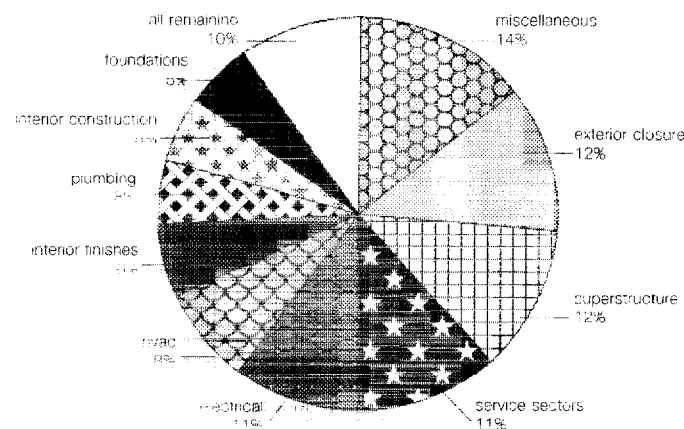
In order to develop a tool that addressed material selection from a full life-cycle perspective, the design team included Pliny Fisk and Rich MacMath of the CMPBS (pioneers in the green architecture movement), and Greg Norris of Sylvatica, a leading industrial ecologist from Harvard. This expanded team, with additional input from Bob Berkebile, Jason McLennan and Dale Duncan of BNIM, developed Baseline Green, a powerful computer program that allows designers to prioritize material environmental impacts, benchmark environmental performance, and make informed, holistic decisions that affect the environment and the economy.

The design team used the initial development of Baseline Green to shape the decision making of material selection for the Pilot building. The final version of the tool was completed in time to gauge the performance of the project compared to the baseline "typical" building with the same programmatic and budget requirements.

Baseline Green allows project commissioners or designers to conduct an upstream environmental analysis of project inputs at several stages during project design, starting at the conceptual design stage where design freedom is greatest. It first groups the several hundred inputs to a building by system category using the popular Uniformat II categorization system in order to aid in summarizing results. Next, it estimates the share of upstream environmental burden due to each input using life-cycle assessment (LCA), based on detailed models of their supply chains and the pollution emitted from each sector of the economy. The results are used to identify which building systems make the highest contributions to the total upstream burden of the project, and which specific inputs within each category rank highest in terms of the environmental improvement leverage they provide, allowing designers to prioritize where to spend their time and money to lower impact. The results can also demonstrate the economic impact in terms of jobs created by the selection of one building material decision over the other by region, county, or state. Decisions can then be made to prioritize materials that minimize pollution while maximizing job creation.

The upstream LCA is accomplished using a model constructed entirely from US government data. Databases from the US Department of Commerce describe the hundreds of inputs to each of over 50 distinct types of new and maintenance and repair construction projects, from new hospitals to repair of electric utility power plants. Other databases from the Department of Commerce provide quantitative models of the supply chains of each project input: specifically, how much of each sector's outputs are used by all other sectors in producing their products. A third set of databases comes from the US EPA, and quantifies the

Figure 2.4.2
Upstream Air Pollution Shares
by Input Categories: MSU
Pilot Building
(Sylvatica + CMPBS + BNIM)



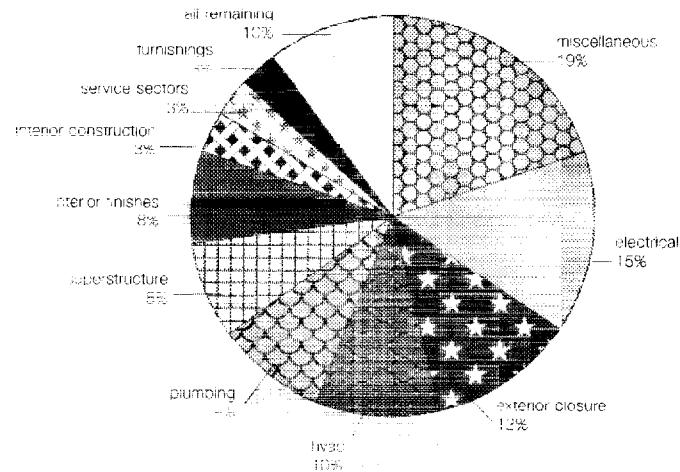


Figure 2.4.3
Upstream Toxic Release
Shares of Input Categories:
MSU EPICenter Pilot Building
(Sylvatica + CMPBS + BNIM)

releases of pollution from each sector as it produces its products. The three sets of databases have been combined to create an input/output life-cycle assessment system for evaluating detailed inputs to construction projects of all types.

A sample output at the category summary level from Baseline Green is shown in figure 2.4.2 and figure 2.4.3 for the MSU EPICenter project. In this application the tool has helped the designers focus their energy on the inputs that matter most for that building type. A surprising aspect of the results is the relative importance of some of the less massive input categories, such as electrical, HVAC, and interior finishes.

Another surprise is the importance of some "service sector" inputs. This category includes electricity sold directly to the construction industry from electric utilities but it also includes inputs to the project from professional service sectors, such as architects and engineers. Recall that for each input to the construction sector, the method performs an entire supply chain life-cycle assessment. Thus, the environmental burdens of Architectural Services include an estimate of the pollution from manufacturing all the paper, office equipment, electricity, and so-on used by the firms; it also includes business travel by A and E personnel, and an apportioned share of the construction and renovation of office space for the industry itself.

Figure 2.4.4 shows the major components of the "Services" category. The results indicate that together, inputs of architectural and engineering services (and their supply chains) account for four to five percent of the total upstream air pollution burden of constructing a building like the MSU EPICenter. To put this into perspective, this is roughly equivalent to the air pollution burdens from all electrical inputs to the construction sector for the same project. It is also roughly on par with the air pollution burden of manufacturing the structural steel for average projects of this size and type. This suggests that striving for more sustainable architectural projects means reconsidering the ways in which architectural services are delivered.

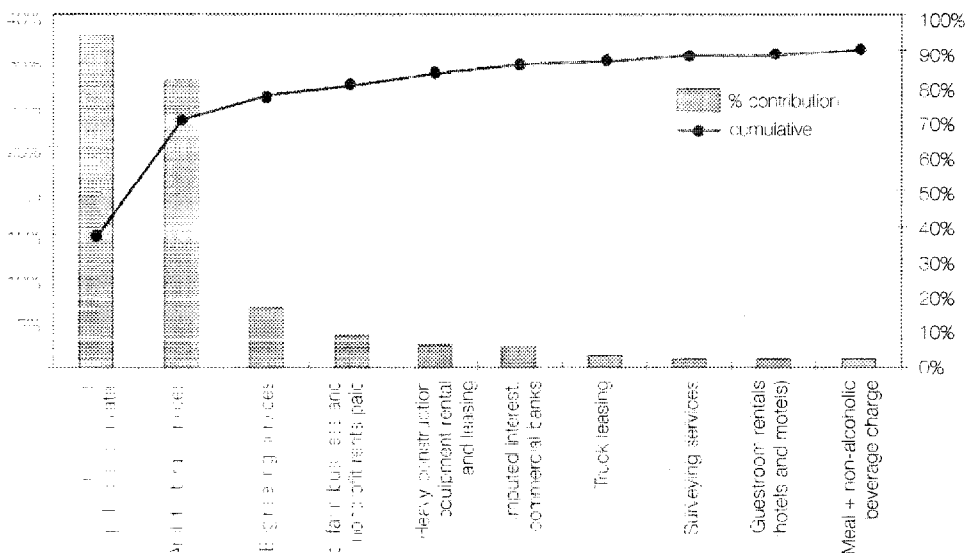


Figure 2.4.4
Upstream Air Pollution Shares
of "Service" Inputs: MSU
EPICenter Pilot Building
(Sylvatica + CMPBS + BNIM)

ITERATIVE APPLICATION OF BASELINE GREEN DURING DESIGN

Baseline Green has been designed to iteratively support and relate to the project design process as it moves from programming through schematic design (SD) to design development (DD). This interactive relationship is illustrated in figure 2.4.5.

After programming, Baseline Green uses databases, which describe the full bill of inputs (materials, products, services, and equipment) to construction projects of over 50 different types. This information is used to create an initial report identifying the key points of environmental leverage for the designers to use during SD.

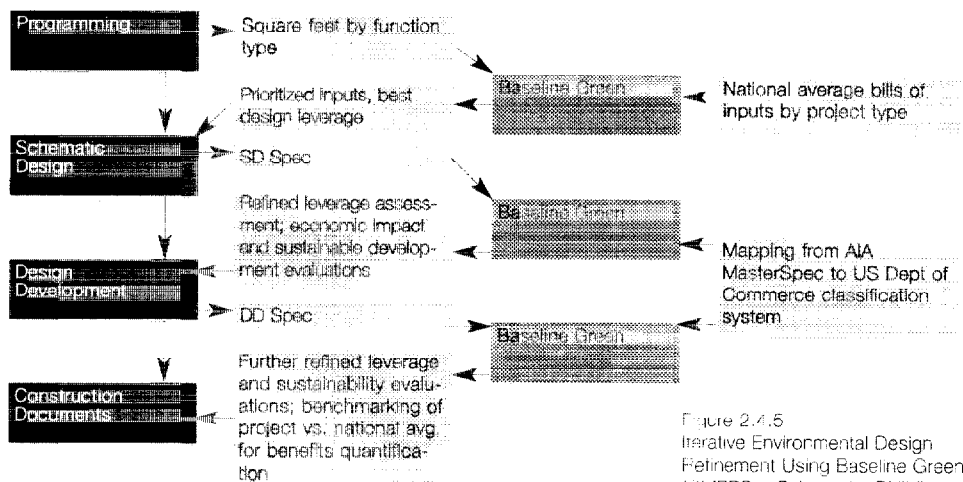


Figure 2.4.5
Iterative Environmental Design
Refinement Using Baseline Green
(CMPBS + Sylvatica + BNIM)

Schematic design produces the SD specification, which is then used with Baseline Green to provide a project-specific input prioritization analysis. This can be optionally combined with an assessment of the regional and national economic impacts of the project specification in order to begin sustainable development evaluation—looking for environmental and economic win/win project design aspects. These are inputs to the design development phase.

A further iteration with increased detail and refinement occurs between design development and construction documents. At this stage it is also useful to compare the project's environmental and economic performance relative to national average performance for the project type. This benchmarking analysis can also be performed earlier during the design process. An example of how Baseline Green can analyze the economic impacts of "green" materials is demonstrated in an analysis performed by Sylvatica of the decision to use the Headwaters product in lieu of conventional precast concrete elements. As mentioned earlier, Headwaters is producing a new product close to Bozeman made from recycled glass for aggregate and fly ash instead of Portland cement. This analysis showed that this decision did indeed reduce pollution in all studied categories while increasing wages within Montana. Not surprisingly, wages were reduced outside of Montana as a result. Baseline Green is an effective tool for local and state governments to prioritize economic investment to attract business locally, while minimizing pollution nationally.

Sylvatica, BNIM, and CMPBS will be using Baseline Green to evaluate environmental and economic performance of some of their projects currently under way. These initial projects will expand the lessons learned from the use of Baseline Green on the EPICenter project and allow the team to continue to improve and expand the capabilities of the tool. As the tool continues to be refined, these firms plan to offer Baseline Green services to projects around the country.

One further step that the team took was to investigate the potential of balancing the amount of carbon dioxide that would be produced through the construction of the building with the amount that could be “stored” within the buildings structure and components using the GreenBalance technique developed by the CMPBS. Rich McMath of the CMPBS performed the GreenBalance analysis for the project.

GreenBalance assessment attempts to “mass balance” the upstream (material acquisition and manufacture life-cycle stages) emissions with the downstream (use and post-use life-cycle stages) “sink” capacity of a given building assembly, component, or material. The objective is to delay, mitigate, or, in some cases, counteract external environmental burdens and their associated societal costs by using long-life, reusable “sink” materials and products derived from renewable and recycled/by-product sources. For the MSU EPICenter Pilot building, the assessment focused on CO₂ balancing of the two most significant building group elements in terms of upstream CO₂ emissions: Superstructure and Building Envelope.

CO₂ BALANCING

The GreenBalance assessment was conducted in five steps:

- 1 A typical structural bay of the Pilot building's south facade was selected as the Superstructure and Building Envelope assemblies to be examined in the CO₂ balancing study.
- 2 The weight of all the various materials and products used in the Superstructure and Building Envelope assemblies were calculated (using the 95 percent construction documents).
- 3 Using carbon dioxide intensity ratios (CDIRs) for each material, the net upstream CO₂ emissions for each material and product and for each entire assembly were estimated.
- 4 Materials and products with lower net upstream CO₂ emissions or with high carbon content (i.e., high CO₂ sink capacity) were substituted in the Superstructure and Building Envelope assemblies.
- 5 The net CO₂ emissions or sink capacity of the revised Superstructure and Building Envelope assemblies were estimated.

The revised design of the Superstructure and Building Envelope assemblies incorporated materials and products that a) used a high percentage of recycled or by-product materials to lower upstream CO₂ emissions and/or b) were carbon dioxide sink materials, (i.e., contained a high percentage of carbon content), such as lumber and fiberboard manufactured from renewable sources. The revised designs did not achieve a net CO₂ balance of zero. However, the net CO₂ emissions of the Superstructure were reduced by more than 97 percent (from about 32,500 lb. to about 1,100 lb.) and those of the Building Envelope were reduced by almost 85 percent (from 11,220 lb. to 1,670 lb.).

OTHER LCA TOOLS

The team also relied on and investigated the potential of other life cycle assessment tools for use on the project. The first such tool tested was BEES 1.0, developed by NIST to address issues of environmental and economic impact on the material selection process. BEES is a product-versus-product decision support tool. Unfortunately, BEES 1.0 contained only a few products in its database and there were concerns about the validity of the supporting data since an undetermined amount came from European sources and was there-

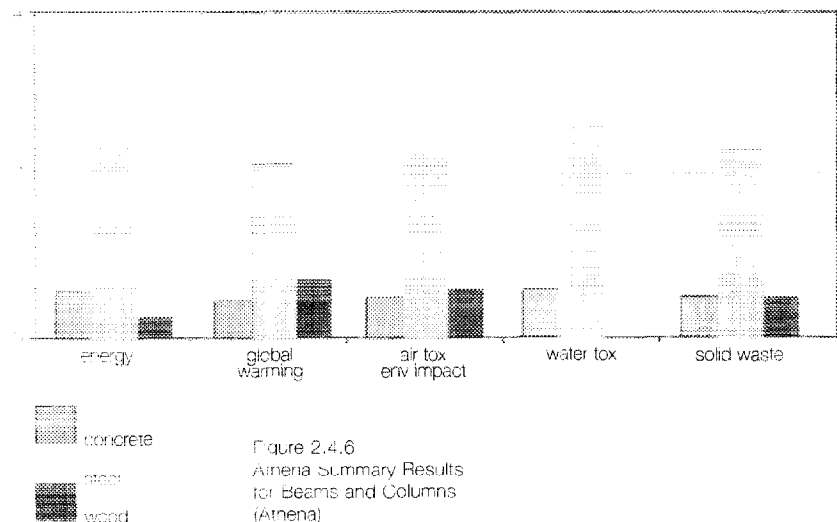


fore of questionable relevance to a project in Montana. After initial investigations into its potential the team ceased its use on the project. The newest version of BEES contains an expanded database and it will be evaluated for use on subsequent projects.

The materials team also prototyped the use of a LCA tool developed by a Canadian group called the Athena Institute. Athena is a whole-building design decision support tool. The Athena databases are populated with regionalized US and Canadian energy production and Canadian data for material production that shares many similarities to American production processes. In fact, a 300-mile radius extended from Bozeman takes in parts of Canada that had regional information available. While the results are not exact, this similarity and proximity provided the team with enough information to observe trends and prioritize material selection based on the results. The design team also found the whole-building design capabilities of the tool worth testing and applying to the project. The Athena Institute is launching plans to produce a regionally focused and publicly available US database for use by all LCA-based building design tools (e.g. BEES, Athena, EnVest, etc.) in the US.

The Athena tool was used by the design team to make design decisions on the structural system for the Pilot building. In addition, according to the results of the initial base lining process in Baseline Green, the structure ranked fifth out of twenty, for both total upstream toxic releases and air pollution. Since the Athena program contains detailed LCA data for specific structural assemblies of different materials, it was particularly useful for measuring the full impact of the design system.

The report analyzed walls, beams, columns, floors, and roofs and described the impacts associated with using concrete, steel, or wood based systems for each. It was interesting that a clear winner did not emerge across all impact categories as might first be expected. The results in figures 2.4.6 and 2.4.7 show that different winners emerge depending on the building component being analyzed. For beams and columns, concrete and wood outperforms steel greatly in each impact category with wood performing slightly better. For floors and roofs, steel and wood do much better than concrete with wood the slightly better performer. For floors and roofs, steel and wood also outperformed concrete greatly with wood generally emerging as the best choice as well. The full results of this analysis are included in the Technical Report, but it is important to remember that these results will vary depending on the region, as each region has different sources for energy generation (coal, hydro, etc.) and different transportation distances to the resources needed.



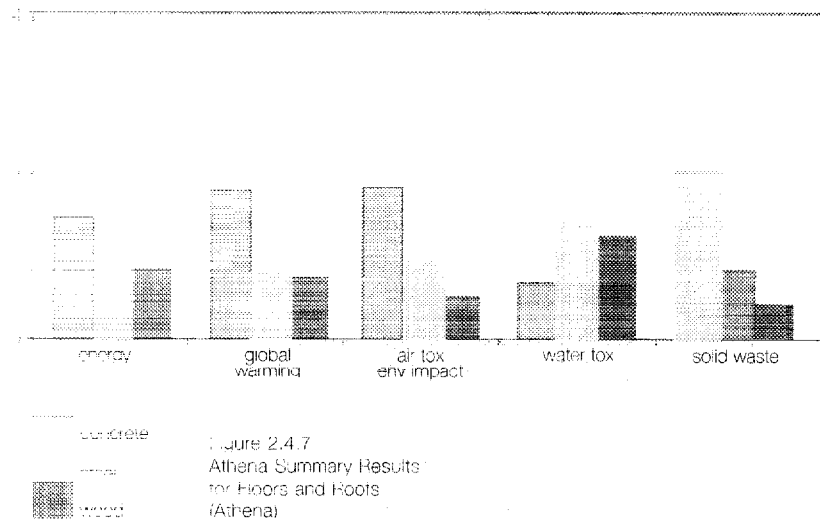


Figure 2.4.7
Athena Summary Results
for Floors and Roofs
(Athena)

The reasons for different winners emerging depending on the use, if not immediately obvious, make sense upon closer analysis. On a per unit basis (pounds etc.), steel has the highest impact (even with recycled content), followed by concrete and then wood. However, in many cases, it takes less steel to perform the same job as concrete or wood, because of its great strength, and therefore it can compete environmentally. In situations where the amount of steel is closer to the amount of concrete or wood needed to perform, steel will then have the higher impact.

For example, using concrete, steel or wood for columns on the Pilot building required columns of nearly identical size and mass and this explained why steel was the poorest performer of the three (due to its high-per-unit impact). Where it is used sparingly, such as in steel stud walls with gypsum board sheathing, steel will perform much better than a solid concrete wall (which requires a great amount of concrete and reinforcing steel). This example also illustrates the importance of viewing material selection in the context of its whole assembly, which may include other materials that dramatically change the environmental performance. Building materials after all, are not specified to work in isolation and should be analyzed as part of a whole system.

As a test bed for the development of the Athena tool and database the EPICenter project has provided a valuable case study for the industry. In the words of Greg Norris, "The team's use of the Athena tool at BNIM in July of 1999 represented, to our knowledge, the first practical commercial application of LCA to real-time, interactive building design refinement in a work session combining architects and LCA experts."

Several lessons were reinforced from the use of the Athena tool:

- The value of quality regional construction data
- The value of materials such as wood that require little transformation from raw material to finished product
- The necessity of viewing materials as part of their total system



CONCLUSION

The project did a great deal to advance the knowledge of sustainable material selection for buildings. From its material radius concept to Baseline Green, the EPICenter helped to break through barriers that building designers face in choosing the most appropriate material for the job. The project also did a lot to help diversify the local economy, minimize waste, and add value to waste materials, where formerly there was none. The next chapter, "Construction Methodologies" describes the team's efforts to further reduce waste during the construction phase of the project.

2.5

CONSTRUCTION METHODOLOGIES

Phaedra Svec AIA

"To create an enduring society, we will need a system of commerce and production where each and every act is inherently sustainable and restorative.... just as every act in an industrial society leads to environmental degradation, regardless of intention, we must design a system where the opposite is true, where good is like falling off a log, where the natural, everyday acts of work and life accumulate into a better world as matter of course, not a matter of conscious altruism."

Paul Hawken, *The Ecology of Commerce*

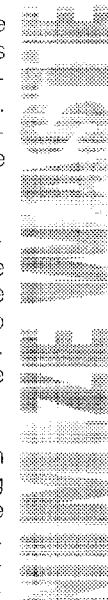
When the life-cycle impact of building materials is studied for the "direct phase" during the construction of a building, it becomes apparent that the traditional construction process is inherently wasteful. Many common construction practices unconsciously magnify the environmental impact of the building while contributing nothing of value to the built environment. The best material selection processes will not realize resource efficiency if the "green" materials specified are cut from the budget, modified in the field, or if significant amounts of the materials are wasted during construction.

The design team for the MSU EPICenter project applied "Plus Ultra" methodology to the construction process in an attempt to identify and minimize waste. The team sought to improve on the traditional bidding process to encourage environmental practices and allow for the responsible and competitive use of public funds. The team worked to bring contractors into the collaboration process early to foster commitment on their part to build more sustainably. The team also sought to stimulate local industry to meet the environmental demands of the project and at the same time minimize regional waste.

The construction process is inherently wasteful because materials are often shipped from great distances and come with excess non-reusable packaging. In case of damage during transportation, materials are often ordered with intended overages. Sometimes materials are handled improperly on site and are exposed to conditions that spoil or contaminate them. Contractors also anticipate that architects will not design utilizing standard modules or components. They often overcompensate by ordering more material than may actually be needed. When asked, material suppliers rarely offer to take back extra materials. Leftovers are thrown into a dumpster along with all their packaging and hauled to the nearest landfill where tipping fees typically cost less than it might cost to process the waste for recycling. All the embodied energy in raw materials, building products, and packaging is left at the bottom of a heap of consumer

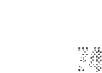


Construction Site (BNIM Architects)



Demolition Waste (BNIM Architects)





waste. If there is demolition, building materials and site debris join the waste heap and contribute to the loss of embodied energy and habitat. Meanwhile, usable materials like the fly ash from the local power plant and wheat straw from surrounding agriculture are wasted along with the rest. With the EPICenter project and the NIST grant there was an opportunity to change this pattern.

The design team set out to evaluate waste in the construction process. Two goals of the project were to develop strategies for converting wastes into assets and to stimulate new "clean" industries and skills related to sustainable technologies and construction. There were several opportunities within the EPICenter project for improvement:

- Minimize the amount of waste created through design efficiency.
- Design integrated modular building systems that will not easily be isolated and substituted.
- Develop new building products made from regional waste products.
- Design for the easy disassembly and reuse of building systems.
- Reduce embodied energy by using products that are made from recycled content.
- Responsibly manage construction waste: reuse and recycle.
- Make waste management intuitive, profitable, and practical.
- Foster education, communication and participation between all parties in the construction process.
- Reduce energy use during construction.
- Minimize negative site impact.
- Use construction cleaning practices that do not negate the indoor air quality goals and related material selection efforts.
- Re-examine the bidding process to ensure that the low bid is also the best value.

When time is money on most projects, contractors and designers don't feel they have the luxury to think about the best environmental solutions. They forget that the best solution to most environmental problems might also be the most economical, efficient, and elegant solution for the building as well. Wall layouts that correspond to standard stud lengths and sheathing sizes save time and money to construct. They utilize all of the material. They simplify the estimating process and lower the price. If designers are knowledgeable about the materials they specify and how they fit into a system, it is possible for contractors to use the materials efficiently and minimize waste. While quality contractors will "measure twice and cut once," it is much easier if they do not have to cut at all.

It is possible to achieve variety in pattern and module if the designer utilizes standard sizes and components. It is only when the designer varies from the standard pieces available that a pristine pattern on paper becomes compromised by what is impossible to build in reality. Awkward details add labor and expense that often lead to modifications in the field.

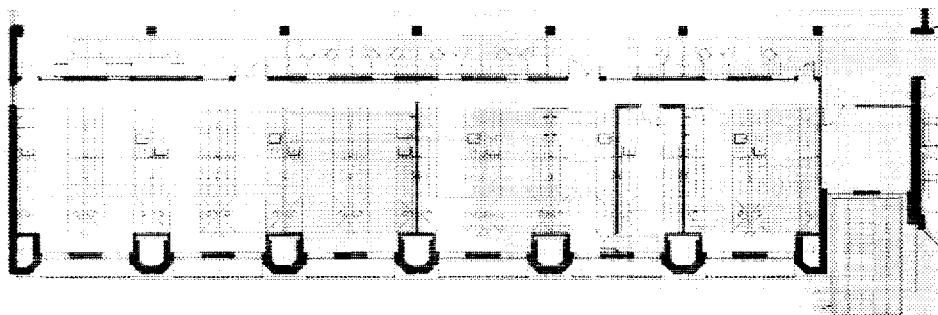
STANDARD MODULES

Sometimes those modifications can be detrimental. The most elegant design solutions come from designers with a rich understanding of the construction process and of the materials they select.

It is natural that contractors and designers repeat what they know to have been the most convenient solution in the past. The status quo becomes a problem when the most convenient solution in the past is not the most appropriate solution for a new or unique design challenge. For designers and contractors to do things that are less wasteful, the process of doing the right thing must be intuitive. When a designer suggests a change to the status quo, the new method must be as convenient as the old method. Taking the time to come up with the most elegant solution for each new design challenge gives designers and contractors a range of choices to make instead of one habitual method that may not fit each situation. The new motto for design and construction needs to be: "Think twice and do it right the first time."


The design team for the EPICenter Pilot building worked to design with modules and systems. Building elevations were designed using standard window modules. Later in the design process it was discovered that the insulated metal panels were an awkward detail because the panels filled the space leftover between standard window frames and structural elements. The overall system could be greatly improved if the panel modules were also taken into consideration as part of the system. Using standard modules results in fewer joints to cause problems with moisture and maintenance. The use of a standard-sized panel also gave the manufacturer more latitude in experimenting with recycled metals. Custom panel sizes would make that kind of substitution cost prohibitive. The use of standard modules would make the manufacturing time a constant so that more time could be spent customizing the detail between the insulated panel and the window frame system.

The design team also used modular lab casework components that utilize a flexible partition system for overhead shelves and equipment. The partition carries all the services for the lab partitions so that the casework can be easily disassembled and reassembled as the needs of the lab change over time. The design of the lab benches was consistent and deliberate to create universal flexibility and to maximize the efficiency of installing lab services.



Lab Casework Plan for the EPICenter Pilot Building
(JUNM Architects)

As important as having an understanding of how to use materials effectively, it is also important for designers to select a pallet of materials that balance the economic, social, and environmental performance of the project. The design team for the EPICenter project developed better ways of understanding the life-cycle impact of those materials. The team learned the value of selecting recycled materials and materials made from regional waste products. This is discussed more in "The Future of Material Selection."



The EPICenter project is a pilot project for testing new construction techniques. The team knew they would face the challenge of convincing contractors and material suppliers to go outside their comfort zones. Contractors have learned to allow a contingency for areas that are unknown and potentially more expensive than anticipated. Sometimes the bids on green building projects turn out to be higher than the cost estimates. This often contributes to the removal of "green" building technologies from the project during a "value engineering" phase before it can truly be determined what they would cost to build.

When contractors are to go into uncharted territory, there must be enough information available for them to make a self-confident bid. The easiest way to do that would be to select a contractor early in the design process and include them on the team as a partner. Montana, however, is a low bid state and bidding regulations require competitive bids.

Sometimes the low bid is the bid with the largest estimating error. Because the bidder is responsible for the budget number, whether it is too high or too low to complete the project profitably, it becomes difficult to ask a contractor to do a little extra for the good of the environment—such as implementing a waste management plan. All the requirements of a green building project must be communicated clearly before bidding so that contractors can build a fair and realistic budget number into their bids.

One solution is for designers to educate contractors about the special nature of the project in pre-bid meetings. A longer-term solution is to sponsor general education in the region before contractors are asked to participate in the bidding process. This process began for the EPICenter project when the project management invited Montana contractors to the 1998 Educational Forum held on campus. In addition, presentations to Montana Contractor's Association, Montana legislators and the Montana AIA focused on this type of education.

In the bidding documents the EPICenter project team introduced the requirement for a waste management plan for the Pilot building (see Technical Report). The NIST Grant funded Doug Jost, a professor of civil engineering at MSU, to conduct a survey of local contractors. He sought their advice about how to best implement recycling programs within their everyday practices. Participating in the survey was in itself part of the two-way process of education between designers and contractors. It helped to identify the barriers to changing the way waste management is typically done. Jost made recommendations about how, from a contractor's perspective, it might be easier to create, bid on, and implement a waste management plan. The surveys also underscored the lack of regional information about what was possible and what was impossible to recycle or reuse in Bozeman. For example, while it is possible to recycle concrete and masonry, there is considerable expense associated with breaking the concrete into an aggregate form that will be accepted by the concrete manufacturers. Even after the concrete is crushed, the manufacturers charge a fee per truckload for accepting the aggregate.

The results of the survey pointed Phaedra Svec and Bob James at BNIM in the best direction for writing a reasonable and practical specification that would allow waste management to be profitable and practical in Bozeman. Svec utilized *WasteSpec: Model Specifications for Construction Waste Reduction, Reuse, and Recycling* from Triangle J Council of Governments, and *GreenSpec: The Environmental Building News, Product Directory and Guideline Specifications* from E. Build, Inc. for much of the specification language and modified it as necessary to make it specific to the Bozeman region.

Jost and Svec set out to create a waste management resource for Bozeman to make local information available to contractors at the pre-bid meeting (see Technical Report). The report includes information about regional opportunities to recycle and reuse construction waste. It is also an opportunity to share goals for reducing energy use and to minimize harmful impacts on the site during the construction process.



The implementation of the plan on the construction site is another opportunity for two-way education between designers and contractors. In the specifications, contractors are asked to make waste management a regular agenda item in their construction meetings. The general contractor is responsible for all subcontractors' compliance to the waste management plan. The contractor is also asked to provide training for construction cleaning crews so that they will not use harsh chemicals and jeopardize carefully planned indoor air quality standards. The hope of the design team is that the Pilot building will give designers and contractors an opportunity to learn how to work together to minimize waste so that in future construction projects writing the specifications, gathering regional information, and implementing waste management on site will become a habit based on proven success.

The EPICenter management team attempted to address some of the problems inherent in the low bid system by reinventing a way to collect fair and competitive bids from material suppliers. Because some of the technologies and materials required to make the EPICenter Pilot building were not yet developed, the team knew the only way to succeed would be to get the Montana legislature to allow sole sourcing, therefore by passing the low bidder process for some items.

The MSU Industry Partners program was designed to do just that (see Technical Report). David Gottfried of Gottfried Technologies (now WorldBuild) worked with Kath Williams of MSU to develop the program's two components. This first was NIST Research and Development of Green Building Technologies, as supported by the US Congressional appropriation. Potential partners made proposals for the acceleration of technologies already in development. The selected projects were included in the NIST Technology Research and Development Program as described in "Technology Transfer and Selection."

The second aspect of the Industry Partners program, the demonstration component, changed the way materials could be specified for the EPICenter Pilot project. To facilitate industry partnerships, the university lobbied the Montana State Legislature to issue an exemption to the low-bid, first-cost only bidding regulations of the state. The exemption allowed MSU to waive the existing bidding criteria and create partnerships with industries that would have potential in the following areas: energy or operational savings over the life-cycle of the building, demonstration of new materials created from recycled materials, or use of indigenous materials that would develop a market locally, regionally, or nationally for that material.

During the course of the EPICenter project over 100 industries expressed interest to partner with MSU to develop and/or supply products. Over 30 made campus visits to explore a partnership with MSU. The companies were motivated by the opportunity to develop a larger market for the new products if they were given an opportunity to demonstrate the technology in a high-profile project. Even with the program's expectation that a minimum 25 percent discount off educational market price be given, the publicity seemed to be enough incentive to lower the price on untried technologies and products.

Industries were also drawn to the project because of the unprecedented feedback loop that would be provided by the MSU end-users. Working collaboratively with the researchers, the students, MSU facilities personnel, and university Safety and Risk Management office, the industries intended to gather data and recommendations for product improvements and enhancements as the products were "put through their paces."

The program also promised to break through the age-old problem of responsibly and competitively spending public funds, while still acquiring the most appropriate products available. It was the hope of the team that working with the industry partner who offered the most

GAINES + LEWIS HALL

appropriate product would spur competition and education among competing companies and help to create future products that would satisfy environmentally responsible criteria. Another hope was that material suppliers would use the industry partners selection criteria as a new state of the art guideline for providing information about the environmental characteristics of their products.

The Industry Partners demonstration program struggled in its trial phases during the renovation of Gaines and Lewis Halls. Because the projects were smaller, the number of participants was limited. Identifying the most appropriate partners meant a process of elimination. As the IPP process was field-tested by MSU, the low bid process crept back into the evaluation of the proposals. When the lowest bid was accepted, the intangible benefits of the product were sometimes overlooked. Because some of the proposed advantages of certain products were difficult to quantify, the potential partners were often asked to go to extreme measures to justify their proposals.

The savings goal of over 25 percent below educational market price was achieved on the limited number of products identified for the program, however, the total savings for the project was minimal in comparison to the total project cost. Amortizing similar savings to the Pilot building yielded questionable cost savings projections in strict accounting terms. The value of long-term research and development partnerships between industry and the university is inherently difficult to quantify.

As a publicly-funded project, the estimate of a construction budget for the Pilot building will become a public document. However, the required competitive bidding process, expected in the spring of 2001, will not allow for dissemination of the estimate in this report. It will be included in the "Afterword," published at the end of 2001.

The promise of the EPICenter Pilot project is that of resource efficiency during the "direct" construction phase of the building's life-cycle. The design lends itself to efficient construction methods and the specifications provide an opportunity for responsible waste management. The exemption from the low bid process will allow opportunities for continued exploration of the benefits of partnering with industry to insure that the most appropriate materials are selected. The regional education that has resulted from of the EPICenter project will carry contractors and designers into future projects with new more sustainable habits.

2.6

IMPROVING HUMAN HEALTH AND PRODUCTIVITY

Jason F. McLennan + Kathy Achelpohl AIA

"We shape our buildings, thereafter they shape us."

Winston Churchill



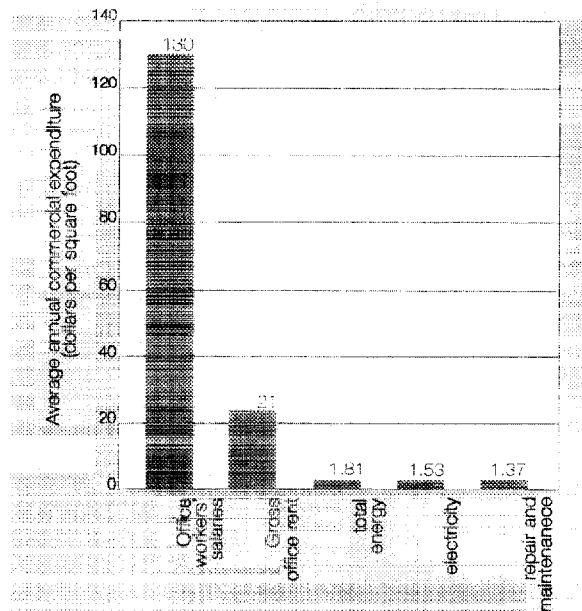
Human health and productivity are greatly affected by the buildings we inhabit. Our physical health and well-being are linked closely to the quality of the environments where we spend our time. Today many Americans spend close to 90 percent of their lives indoors and, not surprisingly, if these indoor environments are unhealthy, it adversely affects individual health and productivity.

The chart shown here illustrates that the most significant expenditure that a company faces is not rent, building operations, or maintenance, but rather the salaries of the employees working for the company.

— one percent increase in productivity from employees represents the equivalent savings of eliminating the entire energy bill. The Rocky Mountain Institute has documented from case studies around the country that green buildings

"show consistent gains in labor productivity of around 6-16 percent when workers feel more comfortable thermally, when they can see what they're doing, and when they can hear themselves think."

These facts, which are now being documented in multiple building types (including schools, offices, post-offices, factories, and retail), are beginning to change how development is shaped.



(Reprinted from *Greening the Bottom Line*, Joseph Pomm and William D. Browning, Rocky Mountain Institute, 1995)

The apparent reasons for the increase in productivity in green buildings are simple. Green buildings are better for people while being better for the environment as well. People respond proactively to positive work environments. They work more productively, have fewer sick days, and complain less to management about comfort.

A green building is one where people have access not only to quality lighting, but a variety of lighting, both natural and electric. The lighting in a green building is designed in direct contrast to the typical sterile, uniformly lit office interior with poor daylighting design—the

GREEN BUILDING PRODUCTIVITY

result of which produces glare, visual discomfort, and headaches. All of this reduces productivity. The green building pays particular attention to visual comfort which includes both attention to the design of the electric lighting (to reduce computer screen glare and eye strain), and the incorporation of daylight and a variety of outdoor views (short and long).

Green buildings also pay close attention to material selection, maintenance, and ventilation strategies. Design strategies to improve indoor air quality (IAQ) are closely linked to human health. Many materials used in buildings can off-gas significant amounts of volatile organic compounds (VOC's) and often require frequent maintenance with additional chemicals that further degrade air quality. Sick Building Syndrome is a direct symptom of poor IAQ that hurts not only the worker, but the employer as well, through sick days and inefficient work hours.

"Productivity-enhancing design requires a shift in your corporate thinking. Companies underinvest in their workplaces in part because they tend to see efficiency improvements as simple cost-cutting, which rarely motivates much management attention or capital spending."

Joseph Romm, *Cool Companies*

Creating healthier buildings—and being able to quantify the human health and productivity benefits of "green" buildings—has been a major concern of the sustainable architecture movement. Human health and productivity are influenced by a variety of factors that include:

- Thermal comfort (temperature, humidity level and ventilation)
- Visual comfort (lighting and views)
- Physical comfort (ergonomics)
- Indoor air quality (material selection, ventilation, operation and maintenance)
- Acoustic comfort
- Olfactory comfort
- Sense of personal control over environment
- Sense of beauty

Promoting human health, well being and productivity was one of the ten original goals for MSU's EPICenter project (see "Introduction"). Two parallel efforts were addressed by the EPICenter team: 1. The Performance team work on the human health and productivity issues that shaped the Pilot building and 2. MSU's Green Research team's work with Judith Heerwagen on human health and productivity methodologies.

THE EPICENTER PILOT BUILDING DESIGN

In order to identify the human health and productivity issues that would shape the Pilot building, the design team began by reviewing the broad goals of the project. The EPICenter project, and later the Pilot building, sought to create a new model for educational facilities that would set new standards for education, collaborative research, and sustainably designed buildings. The EPICenter would foster breakthrough scientific discoveries through a collaborative research environment, and would demonstrate integrated learning approaches to help build bridges from undergraduate education, to research, to industry.

With the broad "Plus Ultra" goals of the EPICenter in mind a number of human health and productivity issues were addressed by the Pilot building design team and in particular, the Performance team members. Building performance was evaluated based on two criteria: energy efficiency and human health and productivity.

Thermal Comfort

Thermal comfort was a key issue for the design team and was a particular challenge to the Performance team due to both the cold climate (Bozeman, Montana) and the immense ventilation requirements of the laboratory fume hoods. The Performance team was a multi-disciplinary group who sought design solutions that solved multiple problems.

During the design of the lab heating system, the design team moved from an air heating system to a perimeter fin-tube system and finally to a radiant floor heating system. Using the air system, the team believed it would be difficult to maintain room comfort without effecting fume hood performance (and user safety). Because the fume hoods were positioned near the outside wall, the perimeter radiation scheme was also abandoned because of its effect on ventilation air currents. In the end, the team decided on the radiant floor heating solution. There is much evidence that occupants are more comfortable at lower air temperatures with a radiant floor system, and the building's efficiency benefits as the radiant system allows a decrease in the supply ventilation temperatures, which reduces the required heating and cooling in the swing seasons. Interestingly, the radiant floor slabs need to be insulated—which is handled in the design using gypsum board panels to conceal the insulation between the floor beams. These painted “panels” become the ceiling treatment in the labs and also provide a reflective surface to maximize daylighting potential.

The Performance team also planned for a wider range of indoor design temperature based on detailed specific knowledge of local climate to achieve “acceptable” thermal comfort with minimal capital equipment, operating energy, and life-cycle costs. This work included specification of higher maximum summertime indoor air temperature based on typical expected lab space air velocities to provide extra cooling effect. During the design process, the team established thermal comfort goals that included:

Space	% of Occupants Satisfied	Temperature Range
Research Lab	85*	68-75 degrees F
Teaching Lab	85*	68-75 degrees F
Atrium	**	60-82 degrees F

* 85 percent satisfied in the labs was the goal and was based on the Performance team's estimate of maximum expected comfort.

** Due to variables in the atrium such as the wider temperature swing, the predicted percentage of occupants satisfied in the atrium needs to be analyzed further by running thermal comfort model equations along with simulations of indoor conditions.

The design temperatures were based on local customary dress and behavior patterns observed in Bozeman and on campus. Acceptable temperature ranges will vary with the seasons. Outdoor temperatures, metabolic rates, and how people are dressed all contribute to thermal comfort factors as well. All too often, buildings are “over cooled” in summer months for how people are dressed resulting in building users feeling “cold” even when it is hot outdoors. The opposite is also true for the heating season.

Visual Comfort

The Performance team's goal for the Pilot building lighting design was to maximize the use of quality daylighting as the primary light source and to design the electric lighting to “fill in the gaps” and blend with the daylight—to provide a quality visual environment while minimizing energy usage. This integrated approach to the lighting design provides a comfortable and visually interesting environment for the building occupants. Objectives include providing appropriate lighting levels, minimizing glare, balancing surface brightness, providing layered





levels of ambient, task and accent lighting, and enhancing the architecture. Another goal related to daylighting was to provide the building occupants with increased contact with the natural environment through more open views to the outdoors, as well as into the biological wastewater treatment facility and its wetlands system (located in a greenhouse, adjacent to student spaces in the schematic plans for the building).

The Pilot building lighting design includes:

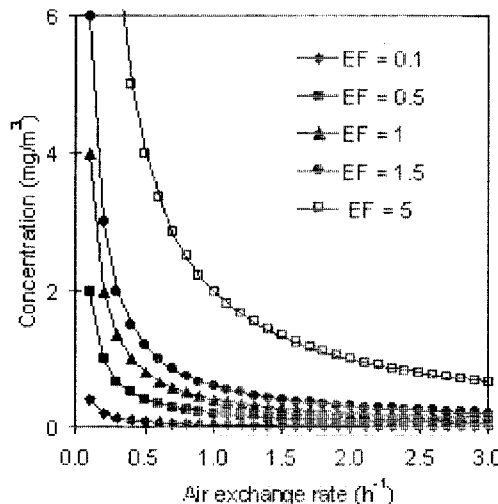
- Indirect/direct electric lighting with daylight and integrated control system to create comfortable work environments in the teaching and research labs
- Task lighting to increase lighting levels for fine detailed tasks in the research labs and at workstations outside the labs
- Localized dimming controls in labs for user-friendly control capability
- Motion sensors to turn off lights when spaces are unoccupied

The design approach includes lighting surfaces, not "volumes," in general circulation areas to provide a comfortable atmosphere for building occupants, and lighting specific areas and events individually. Instead of lighting the entire building, areas are lighted according to their use and character. For example, the workstations outside the research labs are lighted with indirect/direct wall mount luminaires located above the lab observation windows and have task lighting at the work surfaces. The goal of the workstation lighting scheme is to provide comfortable diffuse lighting for computer work and to avoid luminaire brightness that would be reflected in the lab observation windows.

INDOOR AIR QUALITY

The following are some of the primary concepts that the Performance team considered during the Pilot building design process related to indoor air quality:

Building Materials. Specified building finishes will be reviewed for potential emissions of VOCs that might be emitted and cause odor, irritation or toxic effects. The criteria for materials are generally low-emitting, durable and can be cleaned with non-toxic methods and products, thus contributing to good indoor air quality.



Ventilation Rates. Outdoor air supply rates were reviewed to determine their adequacy to dilute potential emissions from indoor pollutant sources. Pilot building fume hood requirements drove the ventilation requirements—a minimum of six air changes per hour will be maintained in the laboratories—so high that there was no concern about the adequacy of dilution air volumes in the research labs.

Figure 2.6.1 Pollutant concentration from various source strengths as a function of building ventilation rate. EF = emission factor ($\text{mg}/\text{m}^3 \text{h}$)

(Reprinted from *Design and Construction of Healthy and Sustainable Buildings*, Hal Levin, Building Ecology Research Group)

CHANGES

Space Pressure Relationships. Adjacent space pressure relationships were specified to minimize the potential contamination through infiltration or air leakage via building construction pathways. The pressure of the laboratories will be negative with respect to adjacent spaces to keep possible spillage and contamination within the laboratory spaces. Careful attention during design, construction and commissioning will provide assurance of the attainment of proper pressure relationships between spaces.

Building Commissioning. Detailed commissioning practices were developed to ensure the adequacy of building performance in all modes of operation, including full and part-load conditions and under all expected weather conditions. The commissioning process will extend over the first year of operation. Technology provided for monitoring building performance will enable commissioning during the first year and beyond for a "continuous commissioning" to ensure continuous building performance throughout its life.

Specification of Non-Toxic Housekeeping. The design team recommended that building housekeeping crews be committed to the use of cleaning products without potential for odor, irritation or toxicity.

Fume Hoods. The design team worked with fume hood prototype designs and recommended that a fume hood operational plan be created to minimize potential for "fugitive" emissions.

Exhaust System. The laboratory fume hood exhaust stacks were designed to provide a high dilution rate at the nearest outdoor air intake during the worst case wind condition.

RESEARCH ON HUMAN HEALTH AND PRODUCTIVITY METHODOLOGIES

Evaluating the human health and productivity of green building users has always been a goal of the EPICenter project. During Phase 2, a multidisciplinary team of MSU researchers was assembled to study this issue, and Judith Heerwagen, a HHP expert from Seattle, Washington, was introduced to the team.

MSU's HHP "green team" included researchers from the schools of Nursing; Education, Health and Human Development; Engineering; and the office of Rural Health. The group sought to develop a measurement and protocol for examining the impact of green buildings on human responses: health, productivity, performance, and environmental values. The team focused their research on the Pilot building addition and existing Gaines Hall. Their primary guidelines were the Pilot building goals: enhanced human health and enhanced student learning and research productivity. The team sought to expand on current research in the field and utilize the opportunity for pre and post occupancy testing.

"Research in this area suffers from a focus on single environmental attributes, such as air quality, to the exclusion of other factors. Furthermore, it also centers on the physical dimension of health and ignores the multi-dimensional view of health that is commonly embraced by the medical profession. The MSU green building human factors project embraces this broader view of health, linking the physical, psychosocial and cognitive dimensions of health."

Judith Heerwagen

Heerwagen has been involved with numerous research projects related to green buildings and human health and productivity and believes that, ironically, many features of green buildings, such as contact with nature and daylighting, are likely to have their greatest impact on cognitive and psychosocial well-being. The table on the previous page provides a summary of the research evidence for the connection between green buildings and well being.

LINK BETWEEN WELL BEING AND GREEN BUILDING FEATURES	
WELL-BEING	BUILDING DESIGN FEATURES
Physical Well-Being	<ul style="list-style-type: none"> Interior cleaning/maintenance HVAC operation and maintenance Ventilation conditions Materials selection Temperature conditions Personal control of ambient conditions
Psycho-social Well-Being	<ul style="list-style-type: none"> Daylight Sunlight Penetration Window Views Contact with nature Social spaces Crowding Acoustical privacy Personal control of ambient conditions
Neuro-cognitive Well-Being	<ul style="list-style-type: none"> Temperature conditions Ventilation conditions Interior cleaning/maintenance Materials selection Personal control of ambient conditions Light levels appropriate for task Lack of glare from ceiling lights/windows Window views Perceived visual distance Contact with nature

Wendy Heerwagen



The "green team" plans to develop a study that analyzes human factors both inside the Pilot building (charting specific environmental conditions and key outcomes) and "outside" the building to understand how green building occupants translate that experience into their beliefs and values. The team has prepared a detailed proposal for future work that includes:

- Creating a MSU profile (as a baseline)
- Examining student and faculty productivity in several areas including time use, psychological intensity during tasks and the physical effects of work in the labs such as user fatigue and ergonomics
- Examining environmental learning: One of the goals of the Pilot building is to educate occupants and visitors about sustainability principles and values conveyed through the building
- Examining student performance (test scores, attendance, evaluation of teachers) and student health (physical, mental and social)
- Testing for physical exposures and environmental sensitivity
- Documenting building use patterns and evaluating occupant satisfaction
- Creating evaluation processes and tools

The EPICenter project made great strides toward setting new standards for designing a quality environment to improve human health and productivity for building users. The ultimate success of the Pilot building can only be evaluated once the building is in use, however the design team is confident that the environment created will be one that enhances the results of the faculty and the ability of the students to learn.

2.1

ZERO POLLUTING EMISSIONS GOAL

Jason F. McLennan + Kathy Achelpohl AIA



If not checked many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it would be unable to sustain life in the manner that we know.

Union of Concerned Scientists

One of the emerging principles of the sustainable design field is the following: waste = food. It's a powerful concept because it acknowledges that in nature there are no linear systems, only cyclical ones. In nature, every by-product becomes a primary product for another system. Nothing is produced that has no "value" to another system and nothing is viewed as waste. Only mankind creates waste that accumulates and pollutes. Buildings play a significant role in this process, as great inputs of energy, materials and chemicals are required to keep them comfortable for human habitation (see "Harnessing Energy from Nature"). All of this "input" produces a significant amount of non-useful output or pollution.

When MSU's EPICenter project shifted from the National ReSource Center to the EPICenter, the problem of pollution generation became an even greater concern for the design team. The typical approach to handling toxic or polluting wastes in a lab building is the old maxim that "the solution to pollution is dilution." Typical protocol is to shoot pollutants generated within the building out of large "cannon fans" into the atmosphere with no treatment. Similarly, trace amounts of solvents and chemicals go down the laboratory drains and end up in the municipal water treatment plant. This irresponsible approach to waste disposal merely sends the pollution "elsewhere" for someone else to deal with. As the world becomes smaller (metaphorically), increasingly we are finding that there is no "elsewhere" and the pollutants that we thought were out of sight and mind have come back to haunt us.

The design team chose to buck this trend, with the "Plus Ultra" goal of becoming the first laboratory building to achieve zero polluting emissions for both air and water. An important distinction to make was the fact that the team was not attempting to eliminate all emissions, which would be impossible and undesirable, but rather to eliminate any emission from leaving the building that couldn't be viewed as "food" for another system. The team also recognized that a zero-polluting emissions building may not be immediately achievable, but would begin with major steps forward and would be improved continually as understanding and technology permit.

"ELSEWHERE"

The team attempted to tackle this problem on various fronts.

1 Recycling

The design team provided space for the recycling of materials within the EPICenter Pilot building, including paper, cardboard and aluminum. MSU has a student led effort already on campus to recycle newspapers, aluminum cans, mixed office paper and glass. The project team also found support in MSU's Safety and Risk Management group who recycle the chemicals used in their experiments.

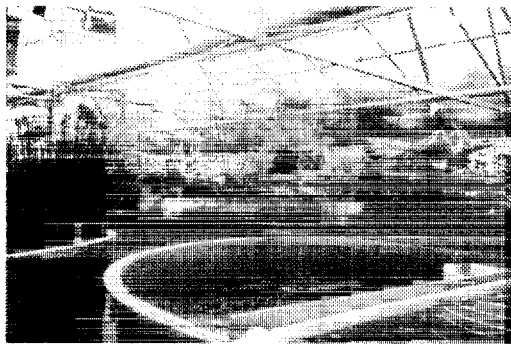
2 Energy Efficiency and Renewable Energy

The design team promoted energy efficiency and began by reducing the Pilot building's energy requirements by using an integrated design approach to minimize the size of the mechanical system. It was planned that all the building's energy needs would come from renewable sources, such as photovoltaics, fuel cells and a nearby wind farm, which, in partnership with Montana Power, would provide clean power. As such, the building would produce no pollution from electricity demands during its operation (see "Harnessing Energy from Nature").

3 Water Collection and Biological Waste Treatment

The design team sought to design a closed-loop water and waste system consisting of rooftop collection and storage, graywater recycling and the onsite treatment of wastewater, using a solar aquatic facility developed by MSU scientists and patented after the "living machine" technology pioneered by Dr. John Todd. The solar aquatic facility consists of a series of tanks, each containing a small ecosystem designed to purify waste. Tanks at the beginning of the system contain simple microbes and plant life, which get more complex as the water becomes increasingly clean through each stage. As it moves through the system, the building effluent becomes food for the organisms.

Livingston Vermont Living Machine
(BNNM Architects)



These three efforts represented state of the art techniques in waste minimization or elimination. But to achieve Plus Ultra status on a laboratory building the design team had to address the problem of chemical waste within the building. The design team searched for technologies and methods to remediate the chemical wastes within the building before settling on two major techniques that were to be prototyped in the EPICenter Pilot building: an air scrubber connected to the fume hood to clean the

pollutants out of the fume hood exhaust; and a research side stream as part of the biological wastewater treatment facility to test the capability of the system to clean chemical waste. The design team realized that the first step in addressing chemical waste in the building was a partnership with the faculty members who were using the chemicals in their research and teaching. Discussions centered on the practice of microchemistry, a technique that is becoming accepted practice in the industry. Microchemistry relies on experiments performed with smaller quantities of chemicals, the result being reduced pollution and expense for the lab. As part of the EPICenter project, MSU professor John Amend helped to develop "green" computer software for chemistry teaching that enabled students to simulate experiments with reduced quantities of chemicals.

REDUCE

Another technique that the design team discussed to reduce chemical waste in the teaching labs was to employ experiments performed "in reverse" to turn toxic chemicals back into their constituent and harmless compounds and elements.

INTEGRATED WASTEWATER MANAGEMENT SYSTEM

A biological wastewater treatment facility was, for the design team, always a part of the EPICenter project beginning with the Phase 1 National ReSource Center that described a solar aquatic facility housed in a greenhouse structure and serving as an aesthetic, pedagogical and systemic centerpiece for the building. As the Phase 2 work began, a group of MSU engineers led by Anne Camper became involved in the project with the goal of advancing state of the art for wastewater treatment. Camper's group proposed to design a system that would utilize established technologies in novel ways, with the following in mind for the final design:

- The facility must be operated in a manner that protects the health and well being of building users and the public.
- The facility should produce a final effluent that can be regarded as suitable for use as (at least) irrigation water.
- The facility should be designed as an educational tool, serving a variety of purposes varying from its value as a demonstration to a hands-on experimental system for engineers and scientists working in waste treatment.
- As much as possible, the facility should make use of "green" technologies, requiring a minimum of power and avoiding the use of toxic chemicals and materials.

The system that Camper's group developed consisted of several components to clean both domestic and laboratory waste:

Domestic Waste Treatment

Primary treatment, (the removal of settleable solids), of the domestic waste stream would occur in a tank (in the basement of the Pilot building) that produces a concentrated slurry of suspended material for further treatment. Primary effluent, the clarified stream leaving the primary treatment system, would be pumped upstairs for treatment in the wetland system (in the greenhouse structure) on the main floor of the Pilot building. Following treatment in the wetland system, the water would be disinfected using a combination of ozone or hydrogen peroxide and ultra violet light, and would then be available for reuse within the building.

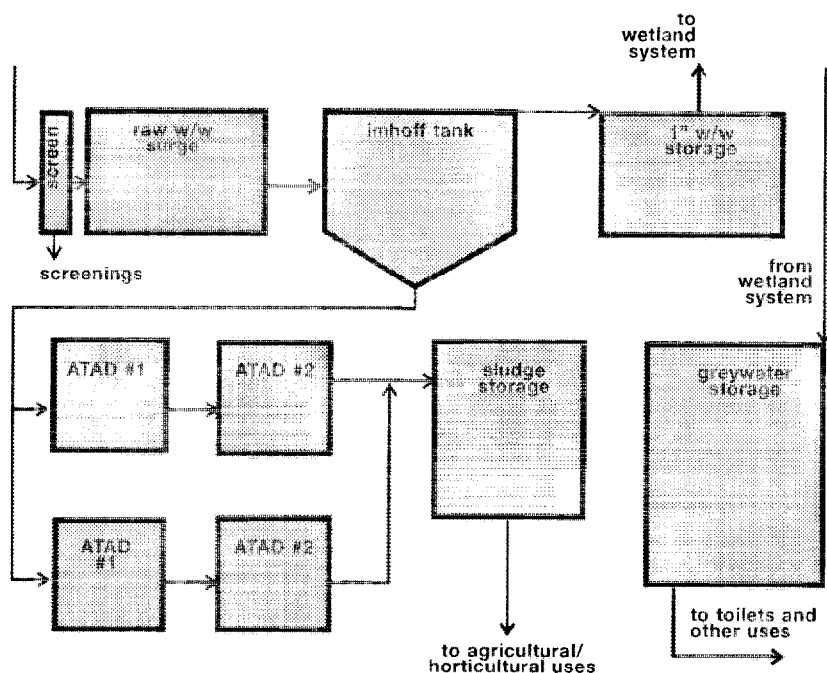
The suspended slurry generated during primary treatment would be treated using an autocatalytic thermophilic aerobic digestion (ATAD) system, which can be thought of as liquid-phase composting, and would utilize excess oxygen produced by a fuel cell to accelerate its performance.

Laboratory Waste Treatment

Chemical waste from the labs would travel to a receiving vessel with an air sparging system. The removed volatile organics would be further treated by CHA's microwave air scrubbing technology, and the remaining water would be treated in the wetland system described above.



Waste Treatment Diagram
 (Camper, Jones, Stein—
 Montana State University)



The research of Camper's group focused on the ATAD and wetlands portion of the system, and their methods and results are summarized in their Technical Report. Specific questions that the group worked to answer included:

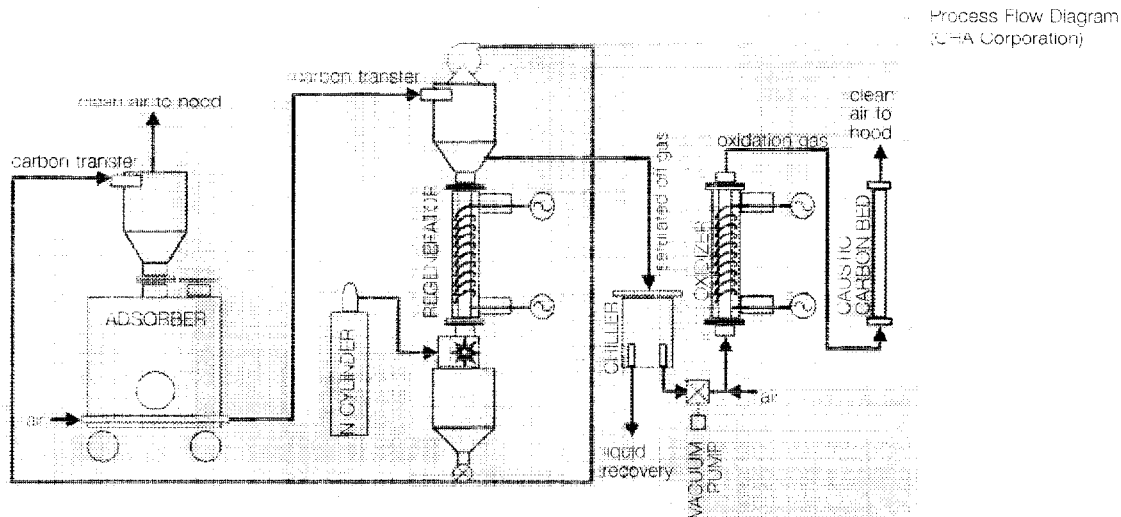
- Could the relatively new ATAD technology be scaled down to the size required for the Pilot building, and how much oxygen would the system require?
- Could laboratory and domestic primary effluent be mixed in the wetland system?
- Would laboratory chemicals kill wetland plants? Could ornamental plants be used in the wetlands to enhance the aesthetic qualities?

MICROWAVE AIR PURIFICATION SYSTEM FOR TREATMENT OF FUME HOOD EXHAUST

Over the course of the project, the design team researched technologies that had the potential to neutralize pollutants from chemicals in fume hood exhaust streams and several technologies were reviewed (see "Technology Transfer and Selection"). Ultimately, CHA Corporation in Laramie, Wyoming, was selected to participate in the NIST R&D program for their proposal to develop a microwave air purification system.

CHA has been working for about 10 years on the utilization of microwaves to induce or enhance chemical reactions, and as a result, has developed several microwave-based chemical processes. CHA's work has focused on their discovery that spent activated carbon could be regenerated for re-use by applying microwave energy. Their work has involved new technologies for air, gas and water cleanup.

During their work with MSU, CHA focused on a new technology to clean chemistry laboratory fume hood exhaust gases. A particular technical challenge for the CHA process was finding a new adsorbent to accommodate the acid and ammonia gases that may be present in fume hood ventilation air, as carbon adsorbents typically used to clean VOCs from the air were ineffective. CHA's first breakthrough occurred when they found that a natural zeolite product absorbs acids and ammonia well and also absorbs microwave energy for rapid regeneration. This new adsorbent can also be reused after microwave regeneration. This breakthrough enables the CHA process to clean a much wider range of multi-component pollutants from ventilation air.



A second breakthrough occurred when CHA replaced the wet scrubber, (that previously they had relied on to remove fluorine, chlorine, bromine and iodine gases formed during microwave regeneration of carbon and zeolite), with a dry active carbon bed. The dry treated carbon bed has several advantages; it is about one-tenth the size of the wet scrubber and produces no liquid waste materials. Interestingly, the two new designs proved to have a higher capacity than any of CHA's existing microwave regeneration reactors. The increased capacity enables the treatment of larger ventilation air streams and removes more pounds of pollutants per hour than ever before. This new increased regeneration capacity has given the CHA Corporation a newfound opportunity to place on-site regeneration facilities throughout the country and the EPICenter project has helped advanced CHA's technology to the commercial sector.

CHA has installed a prototype system in MSU's Safety and Risk Management Facility at the Advanced Technology Park. The installation includes an individual fume hood absorber unit and a separate regeneration system. The regeneration system was sized to handle up to 30 individual absorber units and will receive its first regeneration approximately six months after installation, which is the length of time needed to load the absorber unit with contaminants. The absorber was installed on an existing fume hood in the facility that has significant exposure to solvents and acids. The prototype system will be monitored for one year to determine the system's capabilities to clean fume hood exhaust air.



RESULTS

In the end, the design team believes that it is possible to design a zero-polluting emissions lab building, but it requires in the short term expenses not normally considered in typical lab projects. The wastewater treatment facility was not funded (as part of the Pilot building), therefore the MSU team's system was not included in the final design of the Pilot building. As part of the EPICenter project, their system was prototyped in the lab and research is scheduled to continue with additional funding from the National Science Foundation. CHA is currently commercializing air cleaning units very similar to the MSU developed system in the soil remediation industry. It was in these collective efforts that the "seeds" for creating the "Living Building" took root.

LIVING BUILDING

2.8

THE LIVING BUILDING

Jason F. McLennan



"To emulate nature, our first challenge is to describe her in her terms. The day the metaphors start flowing the right way, I think the machine-based models will begin to lose their grip."

Janine Benyus, *Biomimicry*

From the beginning, MSU's EPICenter project was an attempt to define and make possible a new vision for the future of architecture. The goals, technologies and methodologies pursued in the NIST grant were all small steps toward a future where human efforts to provide shelter and comfort have no more impact than if nature itself were the designer. This vision of discovery relies on the wisdom inherent in living systems and rejects the notion that humans have to "invent" everything. The "Living Building" concept was the culmination of our efforts to achieve all of the goals stated in this report in a simple metaphor, a paradigm shift in the way we approach architecture.

The Living Building concept has proven so powerful that in a short time it has appeared in several publications and has been discussed at a number of conferences (see "EPICenter successes"). Its power lies in the rejection of the "machine as metaphor" so prevalent in the mythology of architecture and technology in western culture. This mythology has been the driver behind humankind's use of nature simply as "fuel" in the machines that give us comfort, allow us to travel long distances, or provide us with food and entertainment.

In its place the Living Building concept inserts the simple flower as a new metaphor for the buildings of the future.



Flowers are marvels of adaptation, growing in various shapes, sizes, and forms. Some lie dormant through the harshest of winters only to emerge each spring once the ground has thawed. Others stay rooted all year round, opening and closing as necessary to respond to changing conditions in the environment such as the availability of sunlight. Like buildings, flowers are literally and figuratively rooted to place, able to draw resources only from the square inches of earth and

sky that they inhabit. The flower must receive all of its energy from the sun, all of its water needs from the sky, and all of its nutrients from the soil. Flowers are also ecosystems, supporting and sheltering microorganisms and insects just as our buildings support and shelter us. Equally important, flowers are beautiful and can provide the inspiration needed for architecture to truly be successful.

Buckminster Fuller, one of the great minds of the 20th century, once said, "We do not seek to imitate nature, but rather to find the principles she uses." And by following these basic principles we can imagine whole cities operating like complex ecosystems, processing water and waste while generating energy. Communities in desert regions will be designed to maximize their ability to collect water and, like the plants of the desert, to retain and conserve that water. In colder climates the focus will shift to retaining heat and capturing the available sunlight. From region to region the focus will change but environmental performance will always be optimized.

BEAUTIFUL

LIVING BUILDINGS WILL

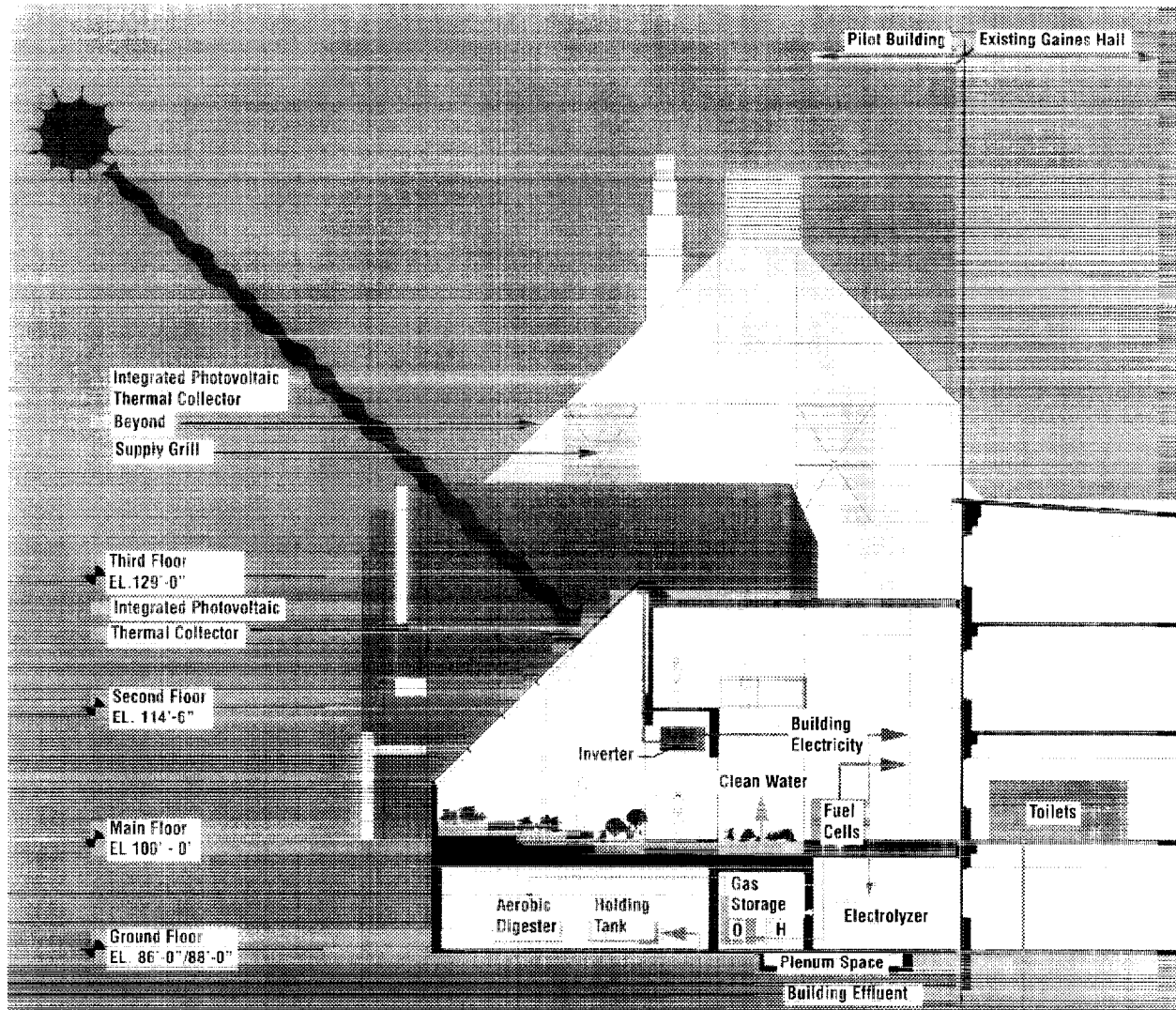
- Harvest all their own water and energy needs on site
- Be adapted specifically to their site and their climate while evolving as conditions change
- Operate pollution-free and generate no wastes that aren't useful for some other process in the building or immediate environment
- Promote the health and well being of all inhabitants-consistent with being an ecosystem
- Be comprised of integrated systems that maximize efficiency and comfort
- Improve the health and diversity of the local ecosystem rather than degrade it—move beyond sustainability to restoration
- Be beautiful and inspire us to dream

Further inspiration for the Living Building came from noted science writer Janine Benyus who reminds us that nature is the ultimate guide for all technology. In her book *Biomimicry*, Benyus asks:

"Is there precedent for this in nature?
if so, the answers to the following questions will be yes:

- Does it run on sunlight?
- Does it use only the energy it needs?
- Does it fit form to function?
- Does it recycle everything?
- Does it reward cooperation?
- Does it bank on diversity?
- Does it utilize local expertise?
- Does it curb excess from within?
- Does it tap the power of limits?
- Is it beautiful?"

Integrated wastewater treatment system for the EPICenter Pilot Building (BNIM Architects)



Perhaps the most compelling example of the living building approach is what the design team called the Integrated Wastewater Treatment System.

This system combined and integrated several systems being considered for use on the project at one time: the biological wastewater treatment system, the integrated hybrid solar collector and a fuel cell (see Technical Report).

The system uses rainwater collected from the roof and stored in a large cistern in the basement. This water is then dedicated to non-potable uses such as flushing toilets (water for drinking fountains still comes from the municipal supply). The water is then piped into a biological wastewater treatment system in a greenhouse on the south side of the building. After being cleaned by the microorganisms and plant life, the water is ready to be returned to the building plumbing system for re-use.

STREET
LEVEL
CO

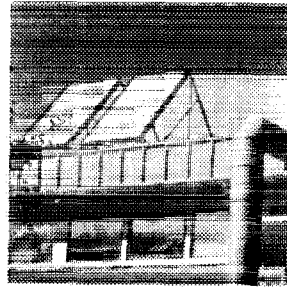


Within this same loop, a portion of the water is diverted and fed through an electrolyzer. The electrolyzer, powered by a photovoltaic array, "cracks" the incoming water into its components (hydrogen and oxygen), storing them in tanks in the basement of the building. The photovoltaics are also used to power the pumps, lights and aerators of the biological wastewater treatment system. At night or during extended cloudy periods, a switch is flipped and the waste treatment process is powered by fuel cells located within the building.

The fuel cells are powered by pure hydrogen stored in compressed form. The pure oxygen is fed into the aerobic digesting stage of the waste treatment system making it more efficient. In this way, several systems are linked and feeding off of each other while producing no pollution at any stage. The system uses only sunlight, water and other living organisms and provides clean water and power for the building. This system as designed, while not as efficient as possible due to current technology, was to be a powerful demonstration of the future and one that answered "yes" to all of Benyus' criteria. Unfortunately, due to a funding shortfall, the wastewater treatment facility was not included in the final design for the Pilot building and the integrated waste treatment system was not fully developed. The diagram remains however as a powerful example of what is possible even today.

In the future, with the Living Building as a new guiding metaphor, our buildings and their systems will increasingly become linked and their environmental impact greatly reduced. MSU's EPICenter project is important because it is a step towards the ultimate goal, a future where our buildings are designed, built, operated, and maintained sustainably.

3



RESULTS

- 3.1 EPICenter SUCCESSES**
- 3.2 FUTURE WORK**
- 3.3 CLOSE**

3.1

EPICenter SUCCESSES

Kath Williams Ed.D + Phaedra Svec AIA + Nancy Harris + Kathy Achelpohl AIA

"When grains of sand are added to a sand pile one at a time, the pile grows until it reaches a critical point at which the addition of one more grain of sand causes avalanches, slides and massive changes. It is an apt metaphor for the way individuals can create sudden shifts in popular understanding and social action."



David Suzuki. *The Sacred Balance*

Lewis and Clark did not find a Northwest Passage, their original goal. Which isn't to say they didn't make significant progress, discoveries, or contributions. Similarly Montana State University's "Green Building" project has not yet reached its original goals of building a classroom and lab building and restoring the biodiversity of the Gallatin Valley in which it is rooted. The achievements in design, prototype development, and the advancement of scientific knowledge, however, have met or exceeded the project's goals.

Measuring success requires quantifiable goals and standards that are clearly identified and articulated prior to commencement of the project. In juxtaposition is the creative process that requires flexibility and innovation. It requires confidence and faith that the team can move beyond what is known to something yet unforeseen. By adopting the "Plus Ultra" strategy the team discovered a method for measuring success that both articulated goals and standards and insisted upon innovation.

Going "more, beyond" took the EPICenter design team and planning committees into realms of discovery often likened to that of Lewis and Clark's Corps of Discovery. Obvious successes of the journey are the four prototype "green" technologies now being evaluated by MSU Safety and Risk Management personnel and the prototype manufacturers. However, the technical experts who collaborated throughout this project point to successes "more, beyond" the required research and development. Ron Perkins of Supersymmetry described this when he wrote, "The first and perhaps most important benefit the grant funds provided us is the time to think 'outside the box' during the pre-design and schematic design process." All of the project's achievements were a direct result of outside the box thinking and many of the challenges came from the inevitable resistance to move beyond the conventional.

There are three primary successes that describe how the EPICenter project fostered sustainable changes.

THE PILOT PROJECT: THE PILOT BUILDING THE RENOVATIONS IN GAINES AND LEWIS HALLS

The EPICenter changes the way buildings are designed, built, operated and maintained.

THE TECHNOLOGY RESEARCH AND DEVELOPMENT PROJECT: FROM GOALS TO SUCCESSES

The EPICenter changes the way educators and industry leaders learn, teach and do research.

THE EPICENTER RIPPLE EFFECT: THE DISSEMINATION OF GOALS, VALUES AND LESSONS

The EPICenter transforms the people and corporations who will bring change to MSU, Montana, the nation and beyond.

GAINES HALL ADDITION

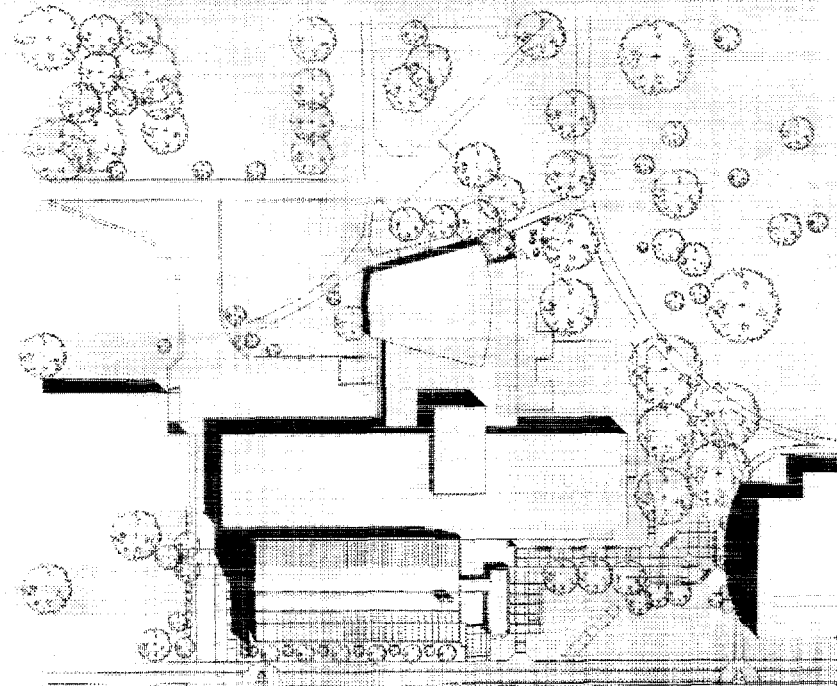
THE PILOT PROJECT: THE PILOT BUILDING

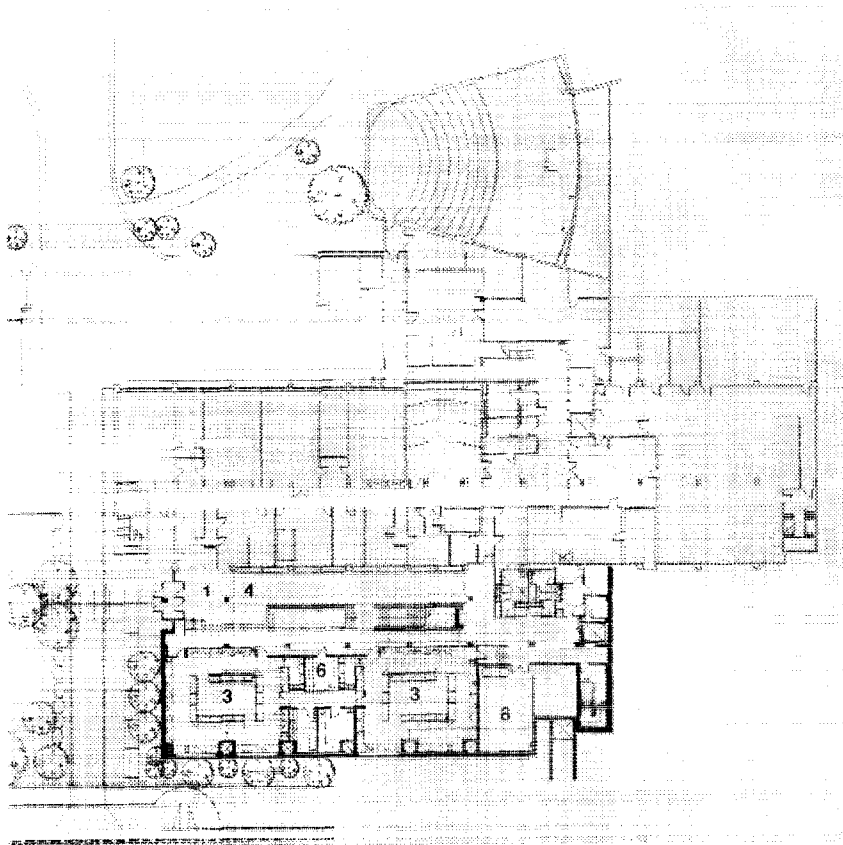
MSU's EPICenter project was a vision of how to change the ways buildings are designed, built, operated, and maintained. The EPICenter would be an integrated learning center where both the science going on within the facility and the sustainable strategies operating it are on display. The building would operate like a living organism, with all systems interconnected for maximum efficiency and minimum environmental impact. New standards and advances would be created in the areas of resource conservation, waste reduction, energy efficiency, and improved human health.

In order to test some of the concepts developed for the EPICenter, and to generate enthusiasm for the larger building project, MSU and the design team developed a design for a Pilot building on the MSU campus. Although not yet built, MSU's Pilot building is considered a success in terms of its innovative design, collaborative design process, and new technology development.

The Pilot building is a four-story addition to Gaines Hall, MSU's Chemistry building and will expand the university's capabilities to complete cutting edge research and teaching in a new setting designed to promote interaction between researchers, faculty, and students. The addition is a 30,000 square foot facility located on the south side of Gaines Hall, and was designed to create a new face for the south side of the campus while showcasing new and emerging technologies both inside and outside the building.

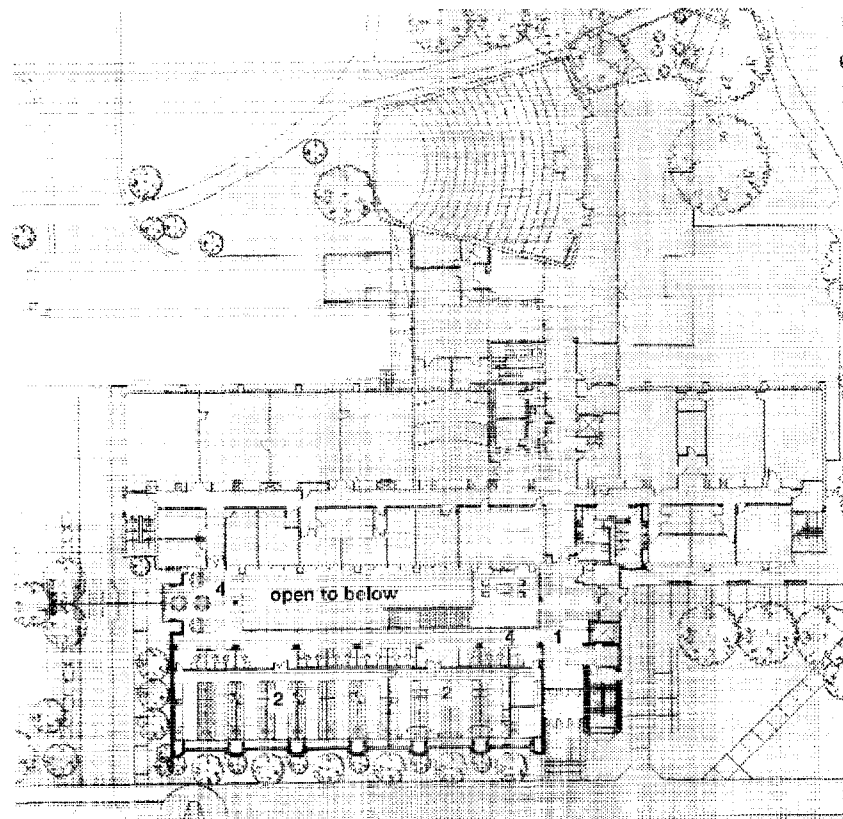
Site Plan
Center Pilot Building
-ENV Architects-



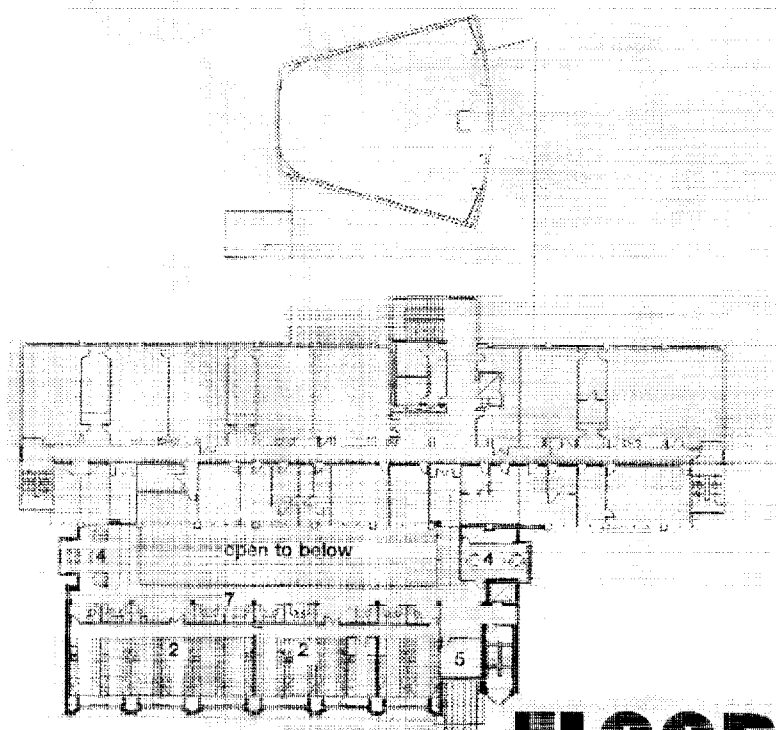


- 1 lobby
- 2 research lab
- 3 teaching lab
- 4 student space
- 5 office
- 6 computer lab
- 7 work stations
- 8 mechanical

Lower Floor Plan
EPICenter Pilot Building
(BNIM Architects)



First Floor Plan
EPICenter Pilot Building
(BNIM Architects)

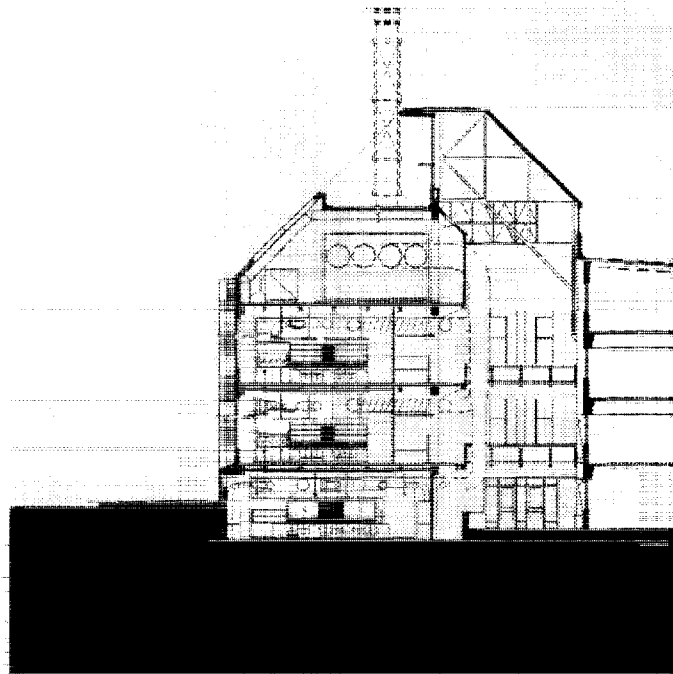


- 1 lobby
- 2 research lab
- 3 teaching lab
- 4 student space
- 5 office
- 6 computer lab
- 7 work stations
- 8 mechanical

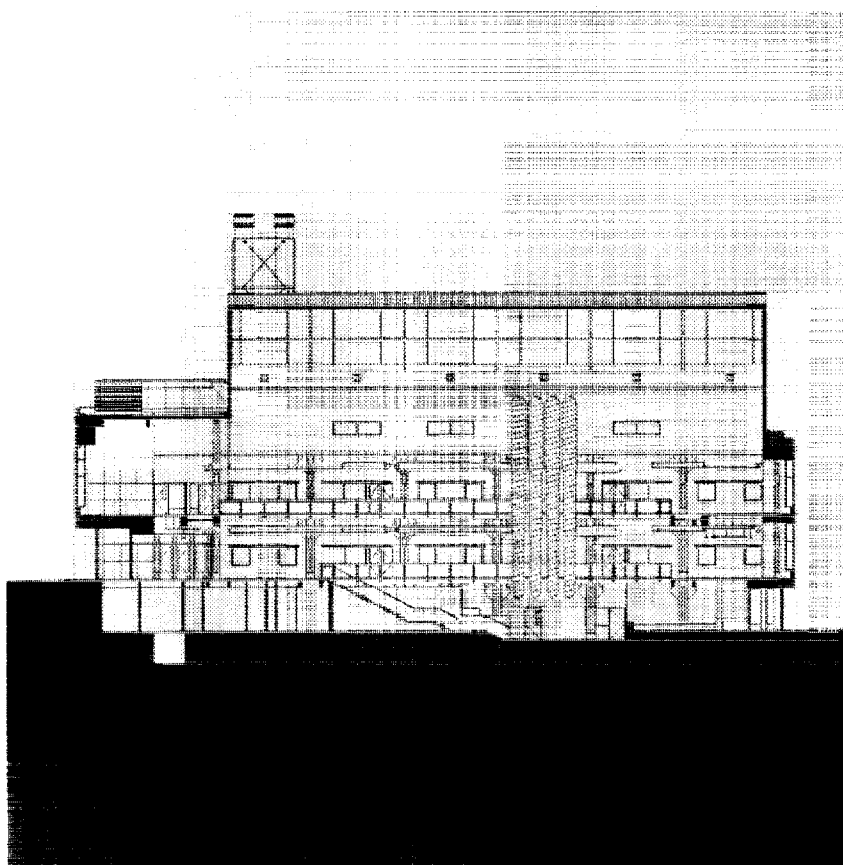
FLOOR

Second Floor Plan
Pilot Building
(JNIM Architects)

* Mechanical Floor Plan
* Center Pilot Building
(HMM Architects)



EPIcenter Pilot Building
Atrium Section Looking West
(BNIM Architects)

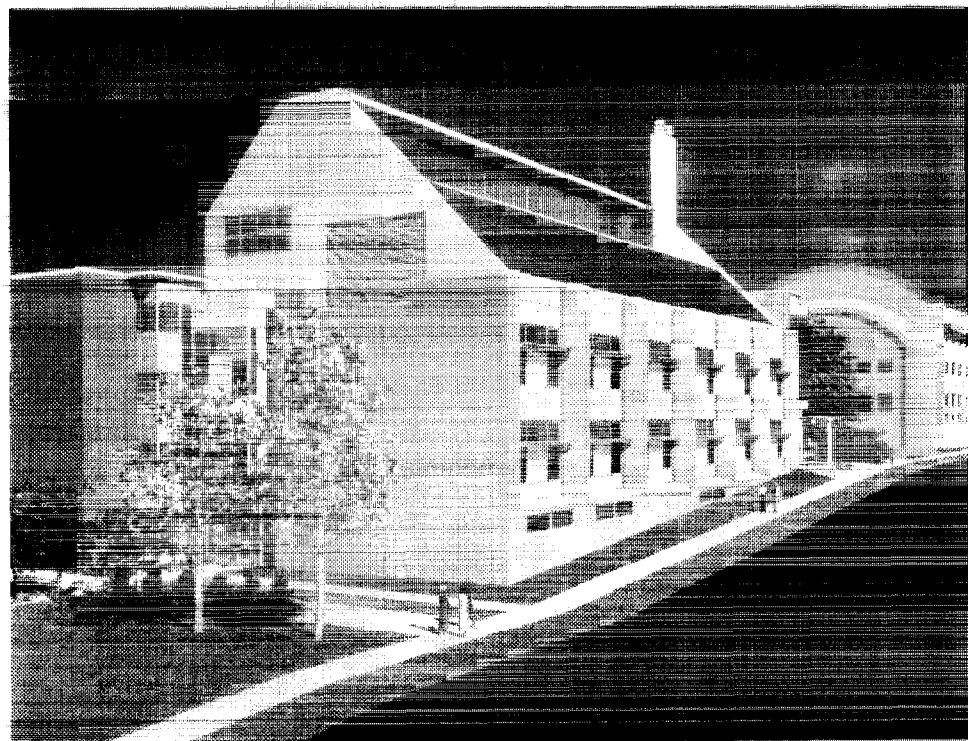
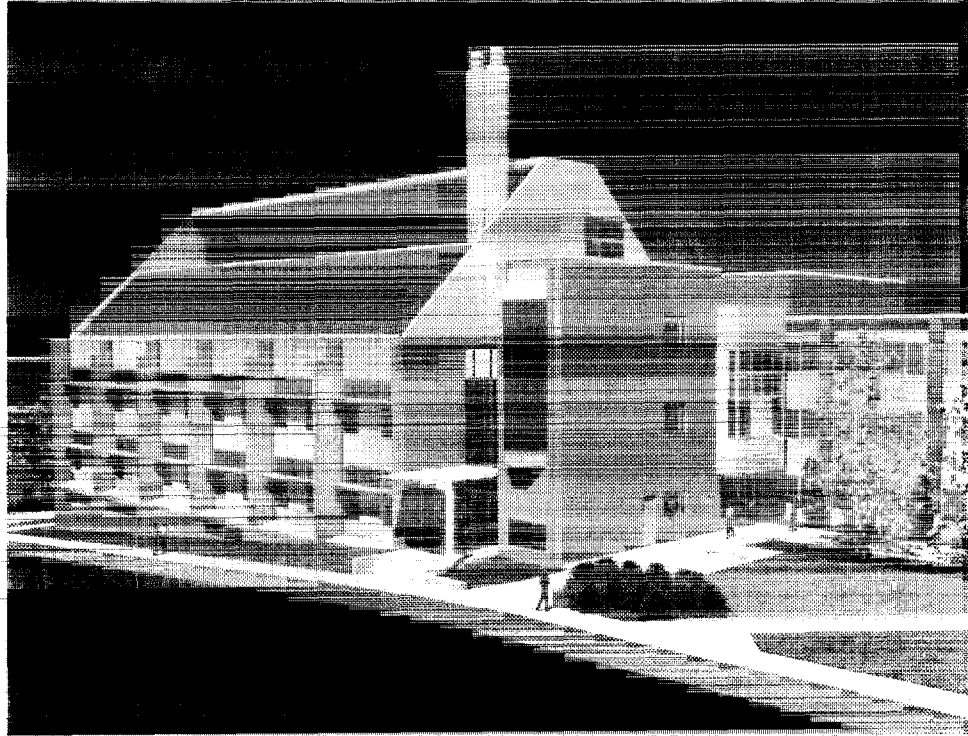


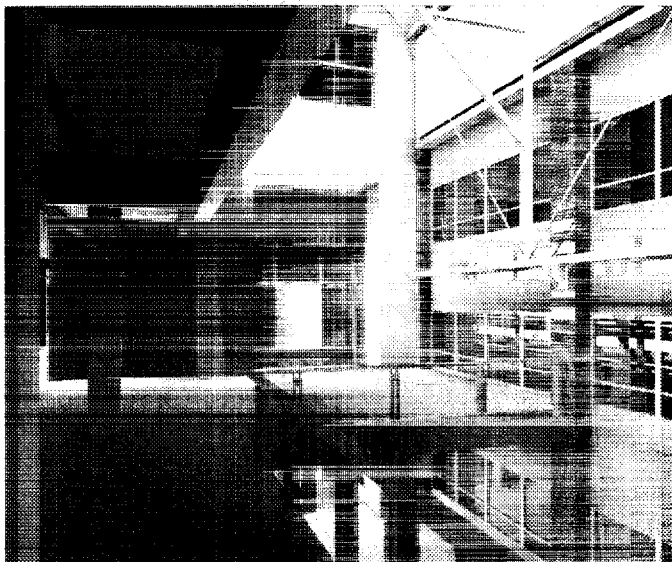
EPIcenter Pilot Building
Atrium Section Looking South
(BNIM Architects)



EPIcenter Successes
MSU + BNIM Architects

FFC Center Pilot Building
 Computer Models
 (HMM Architects)





The building's design is a response to the need for a modern, multi-level structure that can accommodate a variety of uses. The architecture is characterized by its clean lines and use of materials, including brick, stone, and glass. The building's design is a response to the need for a modern, multi-level structure that can accommodate a variety of uses.

EPICenter Pilot Building
 Computer Models
 (BNIM Architects)

FEATURES

The building is organized around an atrium that adjoins the old facility while allowing light into both student spaces and existing Gaines Hall laboratories and offices. The core of the Pilot building consists of 7,000 square feet of research laboratory space for four principal investigators and will contain several prototypes of the latest energy efficient fume hoods. The building was also funded in part by MSU students who were attracted to the idea of having a green building that would house study space in the heart of the campus. Inside the Pilot building, student spaces are located along balconies, filling the atrium space with vitality and energy, and providing a direct connection between the daily activities of researchers, teaching faculty and students. It is envisioned that the atrium will become a new focal point for informal student gatherings on the campus.

The Pilot building is also a pilot project for LEED (Leadership in Energy and Environmental Design), a green building rating system developed by the US Green Building Council. To achieve LEED certification for a building, the design team must implement strategies and measures in the areas of indoor air quality, energy conservation, water use, site design and material selection. Although the Pilot building was designed prior to the completion of Version 1 of LEED, the EPICenter project contributed to defining the criteria ultimately accepted by the USGBC membership in LEED 2.0.

Unique features of the Pilot building include:

Energy-Efficient, Integrated Mechanical System: Integration of many common and some not so common energy savings concepts combine to make the Pilot building Plus Ultra in energy conservation. The Pilot building may in fact be the most energy-efficient lab building ever designed. Concepts include: low pressure-drop/low velocity design, energy-efficient fume hoods, evaporative cooling, ground water cooling and heating, heat recovery, radiant floor heating, and right-sized equipment design.

Naturally Cooled Atrium: The atrium has been designed to minimize the need for mechanical intervention to provide comfort, relying instead on passive technologies that have been adapted to the Bozeman climate. In the summer, the atrium is passively cooled using cross ventilation that harnesses the large temperature swings that occur from day to night.

Integrated Daylighting/Lighting System: South facing laboratories have been designed with new state of the art daylighting design, controls and electric lighting that maximize the quality of light available while minimizing energy and maintenance costs. The atrium space also relies on daylighting and lighting controls to create a quality and energy-efficient visual environment.

Energy-Efficient Envelope: The Pilot building has been detailed to minimize radiant, conductive and convective energy losses through the envelope. High R-values and high performance glazing combine to produce superior envelope construction. The Pilot building will also make existing Gaines Hall more energy efficient—as the currently inefficient south wall of Gaines will be adjoined to the more energy-efficient atrium.

Combined PV and Thermal Solar Collector: Although not funded at the writing of this report, the Pilot building is designed to showcase emerging new energy and thermal generating technologies combined in one roof integrated product. The hybrid integrated photovoltaic panels, designed to be the south-facing roof, would provide up to 20kw of power for the facility as well as a significant amount of hot water generated from coils located underneath the PV.

CAMPUS SPACE NEEDS

Fuel Cell and Electrolyzer: The Pilot building is planned to be a demonstration site for an AvistaLabs proton exchange membrane (PEM) fuel cell that will generate electricity for the building from stored hydrogen. The hydrogen will be created with an electrolyzer that will “crack” water into hydrogen and oxygen.

Demonstration of New Alternative Materials: The Pilot building incorporates a new concrete developed by a Montana company that eliminates Portland cement and uses fly ash as the binder. This new product also utilizes glass from the local waste stream as aggregate.

Monitoring and Controls: The Pilot building will utilize the latest technology in direct digital controls and the building’s performance and operations over time will be monitored by a separate system for initial and continuous commissioning. The Plus Ultra commissioning process goes beyond systems testing and includes analysis of the environment the systems deliver. The goal of the monitoring system is to document building performance with accurate measurements and analysis for use in replicating successful techniques in future sustainable building designs.

Zero-Polluting Emissions Technology: The Pilot building moved closer to the goal of creating zero-polluting emissions for laboratory waste, both air and water. On the air side, chemical scrubbers are planned at individual fume hoods to trap chemicals from the exhaust air stream on activated carbon and natural zeolite. On the liquid waste side, scientists at MSU continue to test the effectiveness of natural wetland systems and microorganisms for waste remediation. Their design will be incorporated in Phase 2 construction.

THE PILOT PROJECT: THE RENOVATIONS OF GAINES AND LEWIS HALLS

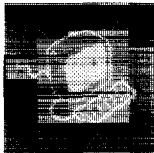
When the decision was made to postpone the EPICenter and build a pilot project, immediate campus space needs had to be addressed. The building committee worked with MSU administration to identify appropriate renovation projects that would meet the current needs of the Center for Computational Biology (CCB) and space that would show progress to MSU students who were contributing funds every semester. The design team seized this as an opportunity to test concepts, strategies, and products that would later be used in the Pilot building.

Accomplishments included:

- Renovation of four existing freshman chemistry teaching laboratories using “green” products
- Creation of lab layouts that fostered collaborative teaching methods and support the integration of the software program developed through the EPICenter project
- A field test of the Industry Partners Program
- Development of a productive, safe working environment for the CCB

THE TECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAM: FROM GOALS TO SUCCESSSES

Advancement of the science of green building technologies was the core objective of the US Congressional appropriations for this project. Understanding this, the founders of the project developed the original vision and goals for the "Green Building" technology and research development program. The team also had a vision of how they would change the way educators and industry leaders learn, teach and do research. The project stayed the course with tremendous successes.



Increase efficiency in flows of information and materials.

The development of the 300-mile radius for material selection was an early success of the MSU EPICenter project. It led to breakthroughs in the development of new materials from the Montana waste stream. These will be discussed later in this chapter.

Montana is a relatively isolated state with few "high tech" industries as a base. The original vision for the EPICenter project included the development of research partnerships with industries that would be of benefit to the students, faculty, the state, and the industries themselves. The Plus Ultra approach to collaboration brought educators, researchers, industry leaders, and students together in ways never imagined before the EPICenter project. As a result the underlying values of the EPICenter project have penetrated the curriculum at MSU and the building industry. The people exposed to the wealth of knowledge and information generated during the seven years of research will create the innovations of the future. The students exposed to these values will build on them throughout their careers.

As a result of the EPICenter project, there have been a number of collaborations that connected MSU with industry:

■ Fisher Hamilton and Lawrence Berkeley National Laboratory forged a relationship that brought forth a prototype of LBNL's Low Flow Fume Hood. The hood was tested and manufactured for the EPICenter project by Fisher Hamilton.

■ CHA Corporation, a small research and development firm from Laramie, Wyoming, welcomed the opportunity to work with major manufacturer, Fisher Hamilton, who pushed CHA "more, beyond," according to Charlie Carlisle, Vice President of CHA Corporation.

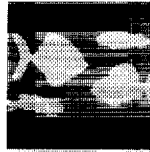
■ Wyoming Sawmills, Inc., Ashland Chemical, Timber Products Inspection, Timberweld Manufacturing, the Forest Products Research Laboratory, and the University of Wyoming worked collaboratively to develop and test large timber beams manufactured from low-grade lumber.

■ Matthew Wood, president of Sustainable Community Development, L.L.C., put together two collaborative projects. The first was with EM Research Organization (EMRO) of Japan and the University of Missouri Departments of Civil and Biological Engineering, and Soil and Atmospheric Sciences. A second collaboration will result in a practical field study at Jefferson City (MO) Wastewater Treatment Facility with SCD, Jefferson City, University of Missouri, EMRO of Japan, EM Technologies of Arizona, and Aries Tek of California.

■ Headwaters Composites will continue to work with MSU professor of civil engineering Jerry Stephens, MSU students, and BNIM Architects to develop appropriate applications for their new materials.

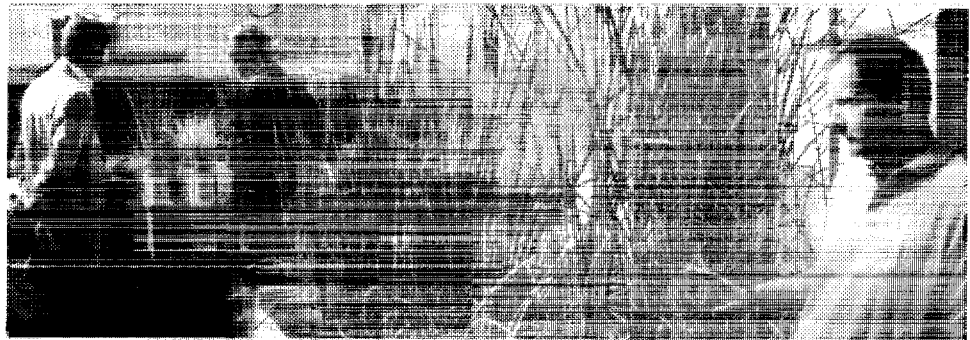
GREEN BUILDING

Constructed Wetlands in MSU's Plant Sciences Greenhouse
(BVM Architects)



Restore biodiversity at the site and neighborhood.

The research in the area of water and waste brought team members closer to understanding the capacity and durability of some indigenous plants and microorganisms and how they work in systems. This research is groundbreaking and one step closer to the eventual goal of finding a sustainable means of pollution remediation.



Building upon the work of John Todd and University of Vermont researchers, faculty members at MSU's Center for Biofilm Engineering developed an on-site biological wastewater treatment plant as part of the EPICenter project. The Biofilm engineers employed undergraduate and graduate researchers and teamed with MSU Plant and Soil Sciences. The performance of woody native plant systems—designed to remediate air, soil, and water pollution—was measured to determine adaptability and tolerance to acid and heavy metal contaminated sites. Early testing suggests that the system has great potential for chemical waste remediation although more research is needed.

The wastewater treatment plant designed by the MSU group is being considered for demonstration by Yellowstone National Park to abate on-going sewage treatment problems and for their new visitor centers.



Improve economic vitality of the community and region.

Identifying products that could be developed from Montana waste streams was a key success of the EPICenter project. The industry partners and other project participants will improve the regional economy by creating useful goods and services and by helping to create a market for waste products.

Headwaters Composites, in Three Forks, Montana, has developed, tested, and secured a provisional patent for a fly ash/recycled glass/borax composite composed of 99.6 percent Montana waste products. This material is currently being explored as an alternative precast concrete and holds great commercial potential. There are also tremendous emission and energy savings in the manufacturing process as compared to Portland cement.

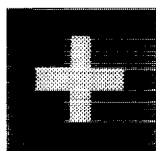
in addition, Headwaters was able to: expand its research staff to include a recent MSU engineering graduate; invent a better small-batch, glass pulverizer that may itself be marketable; and reestablish a relationship with a Billings, Montana, cement producer. EPICenter project management also made an introduction of the product to Holnam, Inc., the largest producer of cement products in the world.

Beaudette Engineering in Missoula, Montana, was the structural engineer for the Pilot building and participated in several research projects. Tom Beaudette and his group helped to test both high percentage fly ash (in the concrete mix) for the Pilot building's structural elements, and the reinforced cast earth product.

James Clinton, engineering faculty member at MSU-Northern, and his students researched the economic and environmental benefits of straw bale construction. They also led the local museum board through a code-exemption petitioning process and secured a building permit for a new wing. A straw bale website has been developed as a deliverable of this project.

Wyoming Sawmills and the Forest Products Research Laboratory continued their research on agro-based binders.

MSU civil engineering professor Doug Jost and two graduate students identified recycling sources for construction waste to maximize regional opportunities.

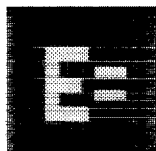


Promote human health, well being and productivity.

The goal of quantifying and documenting behavioral change and even learning as it relates to green building technologies is a difficult challenge. The EPICenter project advanced the development of protocols to measure the impact of green buildings on their users.

Judith Heerwagen, then of Battelle Pacific Northwest Laboratories, was invited to the MSU campus to conduct a workshop to present state of the art for human health and productivity methodologies related to green buildings.

An interdisciplinary team of MSU researchers proposed to use the Pilot building as a beta site to test five research methodologies. The "Green Team" made strides toward protocol testing and baseline data gathering.



Set new standards for energy efficiency and resource conservation (operating energy has priority over embodied energy).

The EPICenter project advanced standards for energy efficiency and resource conservation in all of the ways described earlier for the Pilot building. The prototypes installed at the Advanced Technology Park will undergo benchmark testing over the course of the next year to evaluate their success in surpassing current state of the art. It is planned that the prototypes will lead to commercial products available for future laboratory buildings and renovations.



LBNL Berkeley Hood Prototype
(BNIM Architects)



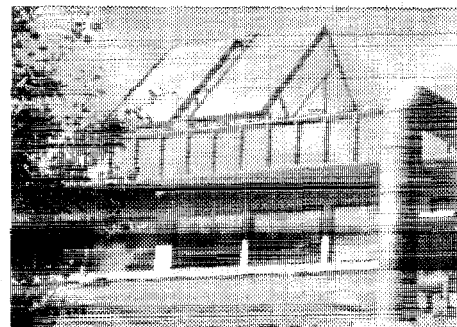
Lawrence Berkeley National Laboratory developed and manufactured a prototype low flow fume hood called the Berkeley Hood that reduces airflow requirements by 50-70 percent.



Fisher Hamilton developed a new energy-efficient fume hood called the Concept 2000 that enables the use of lower face velocities (60 FPM). Fisher Hamilton hopes the prototype will be ready for the market in two years.

Solar Design Associates, SunEarth, and UniSolar developed a hybrid solar/thermal collector called Phototherm. A proof of concept prototype has been installed at MSU for ongoing data collection and analysis.

Fisher Hamilton
Concept 2000 Prototype
Phototherm Prototype
SunEarth Architects

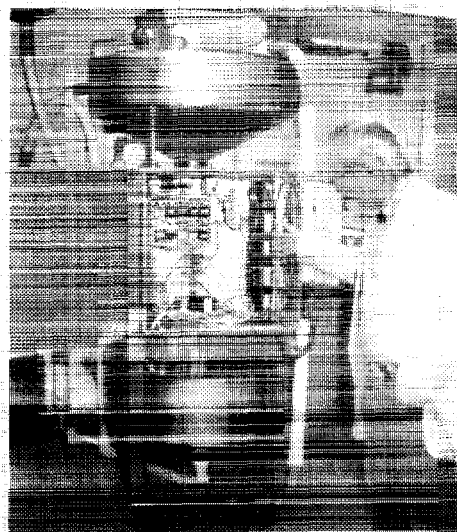


Reduce global warming, ozone degradation and acid rain by increasing efficiency, restoring biodiversity and reducing release of contaminants.

Laboratory buildings typically create emissions problems and waste tremendous amounts of energy—the result of which adds to global warming, ozone degradation and acid rain. The fume hood prototypes will help to minimize energy waste and the resulting pollution. The EPICenter team also addressed the problem of polluting emissions:

CHA Corporation adapted ten years of research on air scrubbing systems to develop a technology to clean laboratory fume hood exhaust gases and to regenerate the filtering materials on-site. To develop their absorber, CHA worked within the parameters for the unit's physical size (3'X3'X3') set by Fisher Hamilton for the laboratory renovation market. The physical engineering challenge was met and the prototype has been installed in the Advanced Technology Park for further evaluation and testing. Because of the success of this project, CHA has secured two other larger projects with major industries and the Department of Defense.

CHA Air Scrubbing Prototype
(BNIM Architects)



LEARN OPPORTUNITIES

The design of the Pilot building proved that it was possible to significantly reduce operating energy demands of a laboratory building and in so doing, reduced CO2 emissions by 300,000 pounds per year.



Improve tools for designing, constructing, operating and evaluating building systems.

The EPICenter project team worked to create a number of new tools to help develop more sustainable building methodologies and practices.

Baseline Green, a life cycle based material selection methodology, was developed by the Center for Maximum Potential Building Systems (CMPBS), Sylvatica, and BNIM and will be used by these firms on future projects to improve the environmental performance of buildings.

The project also supported the development of a sustainable products manual that is part of the successful Sustainable Products Training Coalition and Course being offered nationally.

A unique commissioning process and an innovative building monitoring system have been developed and specified for the Pilot building. It will be an essential model used by all the participants in their future building projects.

Energiv 10 software, developed by the National Renewable Energy Laboratory (NREL), was tested and refined during the first phase of the EPICenter project.

University of Idaho researchers developed instrumentation and methods to determine the stiffness of wood in standing trees.



Explore potential of human resources through education and empowerment as a major factor in environmental performance, human health and economic productivity.

When the students on the Green Building planning committee focused on the name "EPICenter" (Educational Performance and Innovation Center), they thought of a building that would be the center from which multidisciplinary knowledge emanated. They foresaw the ripple effect of what was to be discovered not only by MSU and the team of national experts, but also by every visitor to the building, every person who logged onto the website, every industry that came to partner in the project. They wanted everyone to contribute to the learning process and to take away a lesson learned. They wanted to see human behavior change: in how research and teaching became fused, where student and researcher learned together, where the non-science student was attracted and welcomed within healthy and safe learning environments. This project has had that effect, even before the MSU President and his executive council approved the name EPICenter.

From its inception, an obvious outcome of this project would be the sharing of knowledge on campus and beyond. The students grasped the concept and principles of sustainability almost immediately upon a presentation by Kath Williams and Jim McCray to the ASMSU Senate. They saw the value of life cycle analysis and flexibility in a classroom/laboratory building. Obtaining student buy-in, particularly with financial support through the student referendum, was an important step in the success of the project.



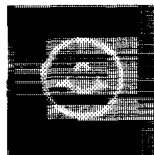
EPICenter Successes
MSU + BNIM Architects

██████████ The National ReSource Center (NRC) was envisioned to be a clearinghouse for green building technology information including public education programs, research partnerships, and a web-based presence for on-line courses, resources, and communication center. Using the USDA Extension Service model, a team of MSU faculty and staff developed a structure and strategic plan for the NRC. Though the actual program has not been funded at MSU, the resource mapping in the NRC project drew national attention through design team presentations at conferences and workshops.

An articulated goal for the MSU EPICenter was to foster multidisciplinary education. The Pilot building design specifically addressed this goal. University researchers and teachers who collaborated on component projects for the EPICenter have now experienced the collaborative process and all its advantages. MSU professors also brought the EPICenter project and the Plus Ultra concepts into their classrooms.

██████████ Wane E. Boysun wrote, "The research process has positively contributed to the knowledge base of the students and two faculty members at MSU-Northern. Our team can use our technical expertise gained during the research process to supplement our current classroom teaching and acquire additional partnerships with industry and national grants related to emission analysis...[The EPICenter project] was an opportunity to learn in a positive team activity." The emissions testing by MSU-Northern produced some baseline data for the Advanced Technology Park and identified challenges to the transfer of measurement devices from one application to another.

██████████ Tom Wood, professor of architecture at MSU wrote, "The support from the NIST grant has improved my teaching and research opportunities. Because of my experience with the variety of software supported by NIST, I was able to receive two grants from the National Renewable Energy Laboratory. My work at NREL included daylight monitoring and energy simulation of the Solar Energy Research Facility and the Visitor's Center on the NREL campus in Golden, Colorado. I have been invited back as a visiting professional to monitor more buildings and to assist with the design team on new projects."

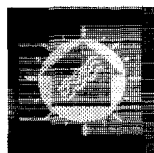


Express "firmness, commodity and delight" (Vitruvius) in the spirit of this region so that the user/visitor can "feel it through their skin" (Deborah Butterfield).

The true success of achieving the goal of "firmness, commodity and delight" can only be determined once a building is built and through the passage of time. But one can imagine that once inside the Pilot building, its occupants will be struck by the abundance of daylight and how it colors the space as the hour and seasons change. One can also imagine that the occupants will feel connected to the outdoors

through views both outside and inside the building—such as the view of the biological wastewater treatment facility where a beautiful landscape will manage the building's waste. Within the "living machine" the team imagines an aquarium that will be a constant reminder to the occupants about the connection between the waste they produce and the lives of the fish and other organisms that process their waste.

AWARENESS



Maximize the pedagogical opportunities of the process and facility.

The goals of the EPICenter were directly aligned with the mission of the university—to provide opportunities for learning. The Plus Ultra step was to make the building itself be a teacher. The EPICenter proposed to do this in a number of ways:

██████████ By putting the sustainable elements and strategies on display in the building (such as the biological wastewater treatment, the low velocity ductwork, etc.).

By giving occupants direct access to the building's performance through touch screen monitors to display energy and pollution saved. These monitors would also include information about the building's sustainable materials.

By empowering the building users who helped create the building to behave differently—with more respect and involvement.

An extraordinary effort was made by the project management and the design team to involve students in the process. Besides the planning committee and campus outreach activities, MSU students made major contributions to the research and development projects:

MSU engineering students were involved in the testing of materials, under the direction of MSU professor of civil engineering Jerry Stephens.

Architecture students worked with MSU professor Tom Wood on daylighting and building modeling.

Biofilm engineers and plant and soil scientists welcomed students into their planning, design, and testing activities for the wastewater treatment facility.

Students in education, health and human development, ergonomics, and nursing worked together on protocol to assess human factors.

MSU student senators were afforded the opportunity to develop, promote, and learn from a "real world" project in which they had a financial stake.

The learning opportunities extended beyond MSU students and researchers to reach industry leaders as well. The ripple effect the projects values will have on industry are only beginning to be discovered.

Fisher Hamilton credits the EPICenter project and Kath Williams' mentorship in attaining their new awareness and change in industry practices toward sustainability. According to Richard Johnson, Product Manager at Fisher Hamilton, they have changed the way they do business forever. They are now striving to become a more sustainable company from top to bottom. On August 8, 2000, Fisher Hamilton celebrated being certified for chain of custody by SmartWood in accordance with the principles and criteria of the Forest Stewardship Council (FSC). The casework manufacturing industry has learned a great deal since Fisher Hamilton and ISEC joined the EPICenter as industry partners. The two companies worked together to recycle in the plant, develop a powder paint application that is less polluting and safer for the workers, implement blanket-wrapping products as a standard, help customers anticipate longer lead times for certified sustainable wood products, and develop tighter definitions for specifications. Fisher Hamilton and ISEC brought the lessons they learned to other projects and to the industry through presentations at conferences like PittCon 2000.

Smaller, regional businesses saw the value of sustainability. Wyoming Sawmills Inc. undertook a project to construct structural laminated beams from low-grade lumber discarded by local sawmills and wood manufacturers. University of Idaho researchers developed instrumentation and methods to determine the stiffness of wood in standing trees. Although the process was difficult and the correlation between stress-wave speeds with modulus of elasticity was low, the researchers did find a relatively high correlation when testing the downhill face of Douglas-fir trees. This encouraged researchers to apply for and be successful in obtaining continued funding from a USDA CSREES Inland-Northwest Forest Products Research Consortium Special Grant.



GREEN BUILDING

THE EPICENTER RIPPLE EFFECT: THE DISSEMINATION OF GOALS, VALUES AND LESSONS

One of the most important successes of the EPICenter project was that it brought discussions of sustainability and Plus Ultra methods and techniques to MSU, the state of Montana, and beyond. The project has transformed the people and the corporations who will ultimately create the change needed to restore the Gallatin Valley and beyond.

As a recipient of a US Congressional appropriation, MSU took seriously the fiduciary duty of sharing data, disseminating results, and passing on lessons learned, and to that end, the EPICenter project director made dissemination a priority. Because of the recognized expertise of the team assembled to design the EPICenter, invited presentations were numerous and often had to be declined if the project work was to be accomplished. The number and quality of the presentations and publications is noteworthy.

The design team and project management carefully chose venues where the audience:

- Was interested in scientific or technical information
- Had potential to be advocates for the project
- Possessed limited knowledge of sustainability but was eager to make changes; or
- Had some relationship with NIST, MSU, industry partners, or design team members

The lessons learned from the EPICenter project will continue to be disseminated by the design team long after the books have been closed on September 30, 2000, and although the project has officially closed, the work of our team members continues.

The following is a partial listing of the invited presentations, journal articles, and general publication pieces that have resulted from the project to date:

CONFERENCES AND PRESENTATIONS

National American College of Sports Medicine (ACSM). Dr. Dan Heit plans to present the validation results of the CSA light monitor, May 2001.

Study of Higher Education's National Conference. Proposal for a presentation submitted by Dr. Kenneth Borland, Dr. Deborah Haynes, and Dr. Clarann Weinert, Sacramento, CA, November 2000.

The Fates of Polar Organic Solvents in a Constructed Wetland Treatment System. Kowles, J.L., Stein, O.R., Jones, W.L., and Camper, A.K. to present at the Montana Section Amer. Wat. Res. Assoc. Annual Meeting, West Yellowstone, MT, Oct. 4-5, 2000.

"Enhancing Human, Environmental, and Economic Performance - Without Increasing First Costs." Northwest Energy Efficiency Alliance and AIA sponsored Architecture and Energy: Building Excellence in the Northwest, presented by Steven Tenney, September 9, 2000.

"The Technologies of Green Building." Kath Williams and Jason F. McLennan. Invited presentation at EPA Labs 21 Conference, San Francisco, CA, September 7, 2000.

EPA Labs 21 Conference. Lawrence Berkeley National Laboratory presented on high-performance hood, San Francisco, CA, September 2000.

"Building Green, Building Partnerships." Kath Williams presented one and one-half day workshop, Oregon State University, Corvallis, OR, August 15-16, 2000.

Biennial Conference in Chemical Education. John Amend of MSU, Dale Hammond of BYU Hawaii, Alex Whittle of Mount Allison University in New Brunswick, and MSU graduate student

Tim Sorev presented green chemistry software during two three-hour workshops at Michigan State University, August 2000.

International Conference on Chemical Education. Dale Hammond and Sophia Nussbaum of the University of British Columbia presented in Budapest, Hungary, in August 2000.

EPA Environmental Protection Agency. CHA Corporation presented air scrubbing and filter rejuvenation technology in Cincinnati, OH, July 13, 2000.

Air and Waste Management Association Annual Conference and Exhibition. CHA Corporation presented air scrubbing and filter rejuvenation technology in Salt Lake City, UT, June 18-22, 2000.

54th Annual Meeting of the Forest Products Society. Wu, Wagner and Gorman of University of Idaho presented lam-lumber stress test research, South Lake Tahoe, NV, June 17-21, 2000.

"Getting Assessment From Faculty: Communicating the brass tacks and the brass ring." A workshop on HHP protocol presented by Dr. Kenneth Borland, American Association for Higher Education Assessment Conference, Charlotte, NC, June 2000.

"Integrated Design: More than just a big team effort." Bob Berkebile and Kath Williams invited presenters, EnvironDesign4 Conference, Denver, CO, May 20, 2000.

General Electric Corporate Research and Development Center. CHA Corporation presented air scrubbing and filter rejuvenation technology on May 10, 2000.

"A Green Building Project: Bringing a campus together." Kath Williams invited keynote speaker, Chico State University's Recycle Week, Chico, CA, April 13, 2000.

U.S. Department of Energy/NREL Charlotte. Kath Williams invited participant on renewable energy team, Washington, D.C., March 29, 2000.

"Environmentally Friendly Laboratory Design and Products." Sponsored by RandD Magazine, presented by Richard Johnson at PittCon 2000, New Orleans, LA, March 13, 2000.

"Collaborative Design in Health Care Facilities Planning." Sponsored presentation by Kath Williams to Michigan AIA annual conference, Shanty Creek, MI, March 10, 2000.

"The EPICenter: A 'green building' in the making." Kath Williams invited workshop presenter for administration of University of Washington, Seattle, March 8, 2000.

AIChE. CHA Corporation presented air scrubbing and filter rejuvenation system during meeting in Houston, TX, March 7-11, 2000.

"Sustainable Campus Planning." Kath Williams selected panel member, Society for College and University Planners (SCUP) Pacific Regional conference, Seattle, WA, March 7, 2000. Second invited presentation by Kath Williams, "Industry Partnerships: Bring Companies to Campus," (highest rated program at conference).

LEED Certification Workshop. Kath Williams participated, Seattle, WA, March 4, 2000.

Teleconference with Architecture and Environmental Studies classes, University of Vermont. At invitation of Maurv Striklyn, Kath Williams presented, January 27, 2000.



Green Partners Conference, Bob Berkebile and Kath Williams invited participants, USGBC/AIA/CSI strategic planning meeting, Seattle, WA, January 23, 2000.

Solar 2000, Green Architecture presentation by Jason F. McLennan, Chattanooga, Tennessee.

Solar 99, Emerging Architecture presentation by Bob Berkebile and Jason F. McLennan, Portland, Maine.

"National Sustainable Buildings Workshop." Kath Williams sponsored presenter and steering committee member, Center for Sustainable Systems, University of Michigan, Ann Arbor, MI, October 9, 1999.

"National ReSource Center for Sustainable Building Technologies." Kath Williams invited keynote speaker, American Association of Housing Educators, Orlando, FL, September 25, 1999.

"The EPICenter: A case study of model laboratories." Kath Williams and Kathy Achelpohl invited presenters, FEMP/EPA Labs of the 21st Century conference, Harvard University, Cambridge, MA, September 8, 1999.

EPA Labs of the 21st Century Initiative. Kath Williams served on steering committee, Harvard University, Cambridge, MA, September 7, 1999.

EPA Labs of the 21st Century. Lawrence Berkeley National Laboratory presented on emerging high-tech building technologies, Harvard University, Cambridge, MA, September 1999.

"Collaborative Design of Green Buildings." Kath Williams and Kathy Achelpohl invited workshop presenters, Society for College and University Planners (SCUP) national conference, Atlanta, GA, July 27, 1999.

"Plus Ultra in Design of Green Buildings." Bob Berkebile and Kath Williams invited presenters, EnvironDesign3 conference, Baltimore, MD, April 30, 1999.

"Green Building Challenges." Kath Williams and David Gottfried invited workshop presenters, National Pollution Prevention Coalition and CURC western regional conference, Stanford University, February 18, 1999.

"Green Building Technologies." Kath Williams invited keynote speaker, Fisher Hamilton Inc., national distributors meeting, Kohler, WI, January 24, 1999.

American Society for an Energy Efficient Economy. Jason F. McLennan presented the "Living Building and MSU," Asilomar, California, 1998.

"Creating Tomorrow's Learner-Centered Environments." Kath Williams, panel participant, PBS/SCUP sponsored video conference, MSU Campus, Bozeman, MT, October 22, 1998.

American Society of Civil Engineers. Kath Williams presented, MSU Campus, Bozeman, MT, October 1998.

US Green Building Council Summit. Kath Williams presented, Big Sky, MT, August 1998.

University of Oregon Sustainability Conference. Jason F. McLennan presented, Eugene, OR, Spring 1998.

NATURAL CAPITALISM

District EPA meeting. Kath Williams presented, San Francisco, April 1998.

State Legislative Committee. Kath Williams presented, Helena, MT, March 1998.

District EPA meeting. Kath Williams presented, Boston, MA, January 1998.

MSU's "Green" Building, presented by Kath Williams, Bob Lashaway and Don McLaughlin to the Bozeman City Commission, Bozeman, MT, December 7, 1997.

Western States PETE Conference. Kath Williams presented, San Diego, CA, August 1997.

"A Model System to Study Mechanisms of Pentachlorophenol (PCP) Phytoremediation in Soil." Miller, E.K., R. Veeh, T. McDermott, and W.E. Dyer presented to International Business Consortium Conference on Bioremediation, Seattle, WA, 1997.

Two presentations by Place Architecture, Bozeman, MT, at regional meetings/conferences.

ASMSU Senate Presentations - Three presentations by EPICenter project chief, Kath Williams, one by Place Architecture, and two by MSU student interns.

Faculty Council Presentations - Two presentations by EPICenter project chief, Kath Williams.

DEMONSTRATIONS

Lawrence Berkeley National Laboratory demonstrations: representatives from many organizations, such as US EPA, PGandE, and CEC have visited LBNL's Industrial Ventilation Laboratory to view the prototype High-Performance Fume Hood, including discussion with members of California Major Energy Users Group.

Montana State University-Bozeman, Safety and Risk Management installation: prototype air scrubber and rejuvenation system designed and manufactured by CHA Corporation, prototype low-flow fume hood designed by Lawrence Berkeley National Laboratory and manufactured by Fisher Hamilton, Concept 2000 energy efficient fume hood designed and manufactured by Fisher Hamilton, prototype photovoltaic solar panel designed by Solar Design and Associates and manufactured by Sun Earth.

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WORLD WIDE WEB PUBLICATIONS

EPICenter Web Site (<http://www.montana.edu/epicenter/index.html>)

LBL High-Tech Buildings Web Site includes the Berkeley Lab High-Performance Fume Hood brochure (<http://ateam.lbl.gov/fhood>; also will be linked to the EPA and DOE Laboratory for the 21st Century Web site at: <http://www.epa.gov/labs21century/lab21init>

WORLD WIDE WEB

3.2

Kath Williams Ed.D + Kathy Achelpohl AIA

FUTURE WORK



"The human race is challenged more than ever before to demonstrate our mastery—not over nature—but of ourselves."

Rachel Carson-Howard Wilshire

Lewis and Clark created the most comprehensive collection of maps and resource catalogs that existed as they explored the west. They also left questions unanswered and more journeys yet untaken for others who followed. The MSU EPICenter project answered many questions and developed much of the technology needed to define a new more sustainable way of building, but much work remains.

Market transformation to more sustainable products is underway through the work of various national movements, like the US Green Building Council's LEED rating system and the promotion of life-cycle assessment tools for material selection such as Athena and Baseline Green. Another way market transformation will occur is through the identification and support for products manufactured from the "waste" processes of industry. For example, test results indicate that higher percentages of fly ash should be considered in the design of concrete structures than those currently being used. These results help to continue the progress of sustainable design and development.

Continuous real-time measurements are vital to document and maintain the performance of building systems over their useful life. Typically, mechanical engineers are not compensated for measuring their designs once built. As a result there is little evidence that one design performs better than another and there is a strong tendency to repeat designs that "worked" in the past without knowing how well they worked. Performance measurement requires that the mechanical design community work with the control industry to develop the necessary sensor accuracy and archiving software. This information should be used in a continuous commissioning of a completed facility.

Macro level health and human productivity analysis looks at building experience holistically rather than at its component parts. Many questions arise as we begin to address how the built environment influences its users. Does experience in a "green" building influence the user's environmental values and health-promoting behaviors? How much experience with a "green" building is needed for positive impact to occur? Can a building influence people who do not experience it firsthand? How do we continue to quantify results?

Because of the breadth and depth of the design teams, many of the design achievements have already been incorporated into current projects. The EPICenter Pilot building design once built, must be monitored, evaluated, and the design refined so that the "holistic building" concept can be adopted or improved based on its results.



Future Work
MSU + BNIM Architects

The commonly held belief that a green building costs more must be challenged and the results documented. Evidence corroborated by the EPICenter team suggests that with proper design, payback time for green features can be minimal (see "Harnessing Energy"). The new tools developed for life cycle analysis will help develop a body of data to change the belief that there is a "green premium."

The expectation of all researchers is that a substantial contribution be made to the body of literature for that science. The design team members, industry partners, and the project management plan to publish results and lessons learned and will continue to actively pursue on-line, real time data sharing from the prototypes developed by this project. Some of the project team's future work is summarized below.

PROTOTYPES

THE PERFORMANCE TEAM

MSU Performance team members (including industry partners) see several essential steps to advance the science of high performance building technologies:

- 1 The evaluation and testing of the prototypes installed at the Advanced Technology Park
- 2 Refinement of the prototypes for manufacturing
- 3 Commercialization of resource efficient products, such as the Fisher Hamilton Concept 2000 Fume Hood, the LBNL Low Flow Fume Hood, CHA's microwave air purification system, and Solar Design Associates' Phototherm (see Power Team)

Development and Commercialization of Prototype Fume Hoods.

Fisher Hamilton Product Manager Richard Johnson says of the prototype hoods, "Only through benchmarking and measuring the performance levels of these products, after installation, will they prove themselves to be successfully innovative to the marketplace and a viable alternative to standard products that are commercially available today." Work must continue with product development and the results measured. Market research is needed to determine the "marketability" and product positioning upon entering the market. All of these results, made possible by the NIST grant, must be shared with laboratory users and the architectural/design community.

LBNL's low flow fume hood work focused on four-foot hoods, and they plan to prototype additional sizes such as six or eight-foot hoods. LBNL has plans to develop and commercialize their new high-performance fume hood lighting system. Promising lines of future research/study include:

- Development of an interface between hood controls and laboratory control systems
- Modification and study of the effects/benefits of supply plenums in advanced fume hood technologies
- Improvement of the hood/sash air bypass and leakage and analysis of the influences of sash-track on containment
- Evaluation and refinement of the rear baffle design
- Study of the effects of different screen meshes, plenum boxes, and outlet geometries on the supply system

In addition, examination of a series of "what if" scenarios to evaluate performance over a range of operating conditions should be conducted to ensure safe operation under all reasonable conditions. Determination of tests that simulate hood use beyond the ASHRAE Standard 110 test need to be made. Also, considerable work and supporting research is required to overcome codes and standards that would prevent or inhibit the use of advanced fume hood technology.

Continued Development of Air Purification Technology. CHA Corporation plans to further develop its microwave air-purification technology to remove and destroy toxic air pollutants from fume hood exhaust. To reduce certain emissions and save natural gas, microwave catalytic oxidation techniques will be developed to replace current thermal and catalytic oxidation. The development of this microwave technology may be extended to the removal and destruction of VOCs generated from dry cleaning and painting operations.

Further Research into the Design of More Efficient and Safer Laboratory Buildings. Shawn Murray, the mechanical engineer of record for the Pilot building highlighted a number of areas for further research to help engineers design safer and more efficient laboratory buildings: 1) Work with manufacturers to reduce pressure losses in fume hoods and air valves; 2) More research on the effect of supply air distribution on the performance and safety of fume hoods; 3) Research in the area of fume hood filtration and the possibility of re-circulating air exhausted from a fume hood; 4) Additional research on the possibility of variable orifice stacks (to eliminate second exhaust stack); 5) Further research on equipment load diversity as the basis for sizing laboratory cooling plants; 6) More research to determine human comfort acceptability ranges with radiant floor heating systems and for evaporative cooling systems in climates where occupants are accustomed to low humidity.

Hal Levin (Building Ecology Research Group), a building ecologist, identified several other areas of further research to design more efficient and safer laboratory environments: 1) Research on the use of passive ventilation schemes in large atrium spaces with large thermal storage capacity in climates with diurnal temperature swings; 2) Research on groundwater use for pre-cooling and pre-heating (delta temperature of the groundwater supplied and returned as well as aquifer temperature); 3) Research on various local occupant control schemes where occupants would be able to request thermal, air movement, illumination or acoustical changes through a microprocessor connected to the building energy management system; 4) Research on how clothing affects thermal comfort in regions with low outdoor winter temperatures.

Continued Development of "Plus Ultra" Commissioning. The Plus Ultra commissioning process relies on high-speed data loggers to handle continuous data collection. Ron Perkins of Supersymmetry will be continuing his work to develop monitoring software that takes the information gathered and presents it. As part of the NIST grant, Perkins has been working with LabVIEW data acquisition software (from National Instruments) that creates user interfaces to give the user interactive control of the software system.

■ **Further Research on Human Factors of Green Buildings.** As part of the EPICenter project a conceptual framework for the study of human factors was developed, specific measures and methodologies identified, and baseline data gathering had begun. As Clarann Weinert of the multidisciplinary "MSU Green Team" points out, "It is particularly important that we have sound, adequate, and appropriate pre-measures of multiple human and environmental [building] parameters prior to the onset of green construction...as a basis of comparison." Many of the pre-tests were accomplished, however, long-range plans await further funding.

THE MATERIALS TEAM

The Materials team identified several areas for further research.

FURTHER TESTING

■ **Continued Development of Waste Stream Products.** The EPICenter project supported the development of waste stream products for two reasons—waste minimization potential and economic development potential. The project team explored several products, including Eco-Baies from waste office paper and a number of Portland cement alternatives. Further testing into the longevity and durability of the materials in different climatic regions should be studied.

■ **Further Research to Reduce Waste and Create New Products in the Timber Industry.** In order to vastly reduce waste and improve the optimization of timber resources, researchers at the University of Idaho worked to develop instrumentation and methods to determine the stiffness of wood in standing trees. Their findings are encouraging and show that a greater number and range of trees should be sampled. Ultimately forest managers could use these new tools to improve their ability to select trees more efficiently.

Wyoming Sawmills plans to continue their work with Forest Products Research Laboratory exploring the integration of agro-based fibers to reduce toxicity of resin binders and to increase beam strength (to reduce beam size and expand structural applications). Also, additional research on the use of new non-VOC adhesives needs to be performed.

■ **The Development of Regional Data Bases and Markets for Construction Waste and Reuse/Recycling Opportunities.** MSU researchers and students developed a resource guide for construction waste in the Bozeman area. Publication of this information and a web-based resource should be developed and maintained.

■ **Refine New Material Selection Tools.** The project team members that developed Baseline Green (BNM, Sylvatica and CMPBS) will continue to refine their life cycle based material selection tool and will be testing it further using future projects in various regions of the country.

WATER AND WASTE TEAM

Water conservation and wastewater treatment continues to be an area for new research.

■ **Further Research on Rainwater Harvesting.** MSU-Northern's rainwater harvesting project indicates that future research should include the monitoring of stored rain water to provide information on the result of long-term storage and changes in water quality in conjunction with the development of biofilms that may affect water quality. Comparison of the efficacy of treatment processes on the long-term storage of rainwater would also be informative. Finally, the design of a gravity filter that could provide filtration without using electrical energy should be investigated.

██████ **Continued Wastewater Treatment Research.** In wastewater treatment, research on removal of polar organic solids should continue, fitting data to kinetic or statistical models in order to draw quantitative conclusions about solvent degradation that can be used in the design of wetland treatment systems. Many local governments currently use land disposal without treatment, which is poorly regulated with likely detrimental impacts. Proof of feasibility of the ATAD system creates an opportunity for pilot testing of the system on septage, with the goal of producing a safe and perhaps even marketable product.

██████ **Further Testing of the Ability of Plants to Remediate Chemicals.** The bioremediation project results indicate feasibility for using plants for remediation of some common laboratory chemicals; propagation efforts were successful for a number of native and adapted species. Further screening efforts may be fruitful in identifying species or species mixes that are optimized for certain waste streams. Such systems could have additional practical applications for bioremediation of other domestic or commercial waste streams.

POWER TEAM

The Power team's primary work focused on the development of the hybrid solar collector and the prototype installed at MSU Safety and Risk Management.

██████ **Continued Development of the Phototherm Prototype.** The Phototherm proof of concept prototype should be developed further to be part of an integrated roof system. This requires the collaboration of the developers Solar Design Associates, and manufacturer, Sun Earth, with a curtain wall/glazing company such as Kawneer. The goal of this collaboration will be to produce an integrated hybrid solar thermal collector that can be certified by Underwriters Laboratories (UL) and the Solar Rating and Certification Council (SRCC) for thermal issues.

██████ **Field Testing and Continued Development of Fuel Cells.** AvistaLabs of Spokane, Washington offered a PEM fuel cell for inclusion as a power source in the Pilot building. The firm is presently field testing beta versions in 2kW units with a "modular" approach to design being recommended. This option was presented by Kath Williams at the DOE/NREL Charrette in April 2000 and adopted by the Power team as an important strategy. Expansion of the field testing along with continued development of fuel conversion techniques are planned by AvistaLabs.

OUTREACH TEAM

The Outreach team identified their future work.

██████ **Further Development of "Green Chemistry" Software.** Professor John Amend's group at MSU will continue to explore the possibilities for inquiry-based chemistry learning and further develop options for web-based and remote laboratory classrooms.

██████ **NRC Development.** If one accepts the US Green Building Council's identification of "green education" as a "No.1 priority," then there remains a need for a National ReSource Center. A strategic plan, developed through this project, would require over \$1 million in operating funds to provide a basic web-based clearinghouse/information center/green library.



■ The Montana State University-Northern straw bale project has been expanded to include a website with materials pertinent to the high line region of Montana. The instructor and students are seeking grants to support continuing operation of the site.

CONCLUSION

The EPICenter project team has been frequently invited to present the concepts, design, technology, and lessons learned in a variety of venues. This work, along with publications, will continue to reach out to those interested in learning more about green building design strategies, performance and technologies that were developed as a part of the EPICenter project.

OUTREACH

3.3

Kath Williams Ed.D

CLOSE



It is the autumn of 2000. As four hikers rest by Spanish Creek, it is easy to look around and see nature changing. Preparations for a long winter are evident. The meadows are spent and tributary creeks are reduced to a dribble. I recall a favorite poem.

NATURE is what we see,
The Hill, the Afternoon-
Squirrel, Eclipse, the Bumble-bee,
Nay—Nature is Heaven.

Nature is what we hear,
The Bobolink, the Sea-
Thunder, the Cricket-
Nay—Nature is Harmony.

Nature is what we know
But have no art to say,
So impotent our wisdom is
To Her simplicity.

Emily Dickinson
*The Complete Poems of
Emily Dickinson*

The EPICenter project that brought these hikers together is also changing. Some parts of the project are going into dormancy, just like the shedding trees. The pilot building design has shown its brilliant colors but must wait in a drawer for new life, hopefully when construction begins in the spring.

As we shared the awesome canyon, Bob Berkebile, Jim Hill, Rick Johnson, and I spoke of why our work had been important. It was comforting to hear shared values:

- ===== Urgency in the need to protect Montana's great beauty
- ===== Pride in the EPICenter team's phenomenal accomplishments
- ===== Reassurance that there are emerging champions to support essential future work and the
- ===== Delight in the extraordinary partnerships the project fostered

All of us knew the project had weathered rough times but found solace that many things about the EPICenter are ever "green." The successes of the NIST research and development project now have lives of their own; many project participants have embraced sustainability and its concepts; the Pilot building design concepts are already being incorporated into real projects and the team members are sharing the lessons learned with audiences around the world.



Much has been learned through the EPICenter project. Two of the simplest lessons:

1 It takes a committed team with shared goals, vivacious spirit, persistence and determination. The best work—taking something “more, beyond”—comes when creative players explore together drawing upon shared values and diverse experiences. As Bill Browning of Rocky Mountain Institute said recently, “Kath, you have the nation’s best team.” It was Dickinson’s Heaven in lots of ways to work as part of this team.

2 Some of us had to learn to be green. Embracing the “Plus Ultra” concept showed many of us how impotent our conventional wisdom had been. We now look at resource conservation not only as the only way of doing business, choosing products, and maintaining the built environment, but as a new “old fashioned” way of thinking. We’ve accepted Nature’s simplicity as the most elegant design.

the EPICenter project played the role of teacher to many more people than “strategically planned,” perhaps many more than the team will ever know. As Bob Berkebile noted in the Preface, this team was on a journey akin to Lewis and Clark. As a team, our discoveries will be debated and discussed like all good contributions to science. We made significant progress as we explored but we did not find our Northwest Passage. There is a need for more Corps of Discovery members on the journey to sustainability.

David Gottfried and Bob Berkebile taught me an important lesson.... that every one of us has a role to play; every one can contribute. Our hike left me in a peaceful state, knowing in some small way that our team made a difference. Now, as the EPICenter project goes dormant, somehow I know there will be a spring when its life will exhibit new vitality.

K.W.

Bozeman, Montana, September 2000

4



APPENDIX

- 4.1 EPICenter HONOR ROLL
- 4.2 EPICenter TIMELINE
- 4.3 BUDGET NARRATIVE
- 4.4 LIST OF TECHNICAL REPORTS
- 4.5 TECHNICAL REPORTS ON CD-ROM

4.1

EPICenter HONOR ROLL

Nancy Harris



With Great Appreciation ...

To All Those Who Have Contributed to Montana State University's "Green Building" Project
1993-2000

ARCHITECTS AND ENGINEERS

Berkebile Nelson Immenschuh McDowell Architects, Kansas City, MO

Bob Berkebile, Kathy Achelpohl, Clint Blew, Dale Duncan, John Gasaway, Bryan Gross, Cathi Hayes, Amanda Halcomb, Bob James, Gary Jarvis, Christopher Kelsey, Mark Kohles, Jason McLennan, Maria Matry, Dan Maginn, Tom Nelson, Anil Panchal, Beena Ramaswami, Monica Rodriguez, Stephanie Sharp, Greg Sheldon, Zack Shubkagel, Elizabeth Smith, Phaedra Svec, Jay Tomlinson, Andy VanBlarcum, Stefania Vigarani, Sherry Van Dorn

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CTA Architects

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Harry Gordon

Andropogon Associates, Philadelphia, PA

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Short-Ford Associates, London, England

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Terracon, Billings, MT

Paul Reynolds

Industrial Services Group, Billings, MT

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Brad Schlepp 1997-1998
Mat McKamey 1998-1999
Jared Harris 1999-2000
Kira Kountz 2000-2001

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Bridger Alternative School, Bozeman, MT

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Cable News Network's Captain Planet Foundation, Atlanta, GA

Sona Chambers

Carrier Corporation, Syracuse, NY

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Center for Resourceful Building Technology, Missoula, MT

Steve Loken, Rod Miner, Tracey Mumma

CONSULTANTS: "GREEN" AND "SPECIALTY"

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Environmental Protection Agency, Laboratories for the 21st Century Initiative

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
Rochev Hobauhn, Bozeman, MT

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George Kanta, Kanta Products, Three Forks, MT

Mat Kraska, Bozeman, MT


 Dana Kuglin, Bozeman, MT
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 Ray Rasker, Wilderness Society, Bozeman, MT
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INDUSTRY PARTNERS: DEMONSTRATION PROGRAM


 AFM Paint, AvistaLabs, Inc., CED, Fisher Hamilton, Forbo Industries, Herman Miller, ISEC, Johnson Controls, Lightolier, Osram Sylvania, Owens Corning, Phoenix Controls, Milliken, Trespa

INDUSTRY PARTNERS: RESEARCH AND DEVELOPMENT PROGRAM


Fisher Hamilton, Inc., Two Rivers, WI

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ISEC Corporation, Denver, CO and Seattle, WA

 Steve McKenney, Dennis Morishige, Jerry Adams, Valerie Ross, Kenneth Li, Paul Hehn, Branden Derks, Tim Reoden


CHA Corporation, Laramie, WY

 Chang Yul Cha, Charlie Carlisle, Bob Guffey, Nathan Boyt, Koby Bracken


Lawrence Berkeley National Laboratory, Berkeley, CA

 Dale Sartor, Karl Brown, Geoffrey Bell, Steve Selkowitz, Eleanor Lee, Charlie Williams, Rich Wilson with research partners Labconco, Fisher Hamilton, ATMI, Phoenix Controls, Siemens, DOE, CEC, CIEE, and PG and E


Wyoming Sawmills, Sheridan, WY

 Ernest Schmidt, Chris Wallace, Rob Ericson with research partners University of Wyoming, Laramie, WY, Timberweld Manufacturing, Billings, MT, Ashland Chemical, Timber Products Inspection, Forest Products Research Laboratory, Madison, WI

Headwaters Composites, Three Forks, MT

 Charles Hedley, Deborah Hedley, Todd Quigley

University of Idaho/Boise Cascade, Moscow, ID

 Thomas Gorman, Francis Wagner, Shih-Yin Wu and research partner David Pollock (Washington State University)

Solar Design Associates, Cambridge, MA

 Steven Strong, Paul Wormser, Joe McCabe with research partner SunEarth, Inc., Ontario, CA

136 Italiano and Partners, Washington, D.C.

Mike Italiano

MSU CAMPUS "GREEN" RESEARCH PROJECTS

Center for Biofilm Engineering - Design of an innovative wastewater treatment system

Annie Camper, Warren Jones, Otto Stein, Janet Kowles

College of Architecture - Lighting and energy simulation research

Tom Wood

Department of Chemistry - Development of Inquiry Centered Learning project (ICLI)

Faculty: John Amend, MSU, Bruce Ivey, Union College, Anguin, CA

Students: Zheng Tan, Mark Rollins, Adina Ragenovich, Scott Furois, Tim Sorey

ICLI Advisory Team: Sophia Nussbaum, The University of British Columbia

Dale Hammond, Brigham Young University Hawaii

Richard Hermens, Eastern Oregon University

Norbert Pienta, The University of Iowa

David Fitzpatrick, Charlo H.S., Charlo, MT

Mike Davis, EduLynx, Inc.

Susan Mason, EduLynx, Inc.

Ron Furstenau, US Air Force Academy, Colorado Springs, CO.

Alex Whittle, Mount Allison University, Sackville, NB, Canada

Extension Service - Development of the National ReSource Center for Building Technologies

Mike Vogel, Laura Estes



College of Nursing, College of Health and Human Development, Office of Rural Health—the"Green" Team"- Research on the impacts of "green" buildings on human health and productivity

Clarann Weinert and Deborah Haynes, co-PIs, with team members John Amend, Randall Batchelor, Kenneth Borland, Shelly Butler, Patricia Butterfield, James Dixon, Tim Dunnagan, Lynn Gibson, George Haynes, Dan Heil, Brian Higginson, Holly Hunts, Chris Keller, Paul Kraft, Vicki Kraft, Pat Lynes-Hayes, Suzi Matthis, Owen Murphy, Richard Petersen, Jim Robison-Cox, Rik Scarce, Debbie Smith, Eileen Ryce, Marie Soller, John Vollertsen, Melinda Watschke, Shawna Yates and Dave Young

Plant and Soil Science - Phytoremediation research

Williams Dyer, Rick Bates, Timothy McDermott
with research partner,
Bitterroot Restoration Inc., Corvallis, MT

Pollution Prevention Program -Construction waste reduction

Doug Jost

College of Engineering -Materials testing

Gerry Stephens

Montana State University-Northern, Havre, MT/GE Transportation

Greg Jergensen, James Clinton, Gregg Hester, Wane Boysun, Mike Rao, Darryl Thackeray, Vern Gagnon, Roger Barber, Tom Reynolds, Maggie Irvine



EEECenter Honor Roll
Nancy Harris

INDUSTRY CONTRIBUTORS

Alpine Industries, Antiquus Wood Products, Armstrong, AT&T, Autodesk, Ballard, Battelle Pacific Northwest Laboratories, Bovis Construction, Chicago Metallic, Collins and Aikman, Collins Pine, Corbond, Eco-Bale Construction, Eco-Products, Ecology Service Products, Edsall Construction, Energy 2000, Enron, Flow Safe, Four Seasons Sun Rooms, Genlyte/Lightolier, Global Environmental Options, Haworth, Holothane, Honeywell/Phoenix Lab Solutions, Hyalite Environmental, IBM, Interface, Kanta Products, Kawneer, Kewaunee, Kimball, KP Office Interiors, ES Power, Inc., Labconco, McCarthy Construction, Nielsen Dillingham Builders, ONSI International, Osram/Sylvania, RC Electronics, Rochester Midland, Shaw Industries, Sidney Mill Works, Silicon Graphics Inc., Solarex, Space, Steelcase, the Durst Organization, Timberweld Manufacturing, Tri-Jack, Universal Air Technologies, Viracon, WattStopper

Kansas State University, Manhattan, KS

Kirby Chapman

LOBBYISTS

Van Scoyoc Associates, Inc., Washington, DC

Ctu Van Scoyoc and Carolyn Fuller

Montana's Congressional Delegation

Senator Conrad Burns and staff

Senator Max Baucus and staff

Representative Rick Hill and staff

MSU Students who faithfully served on the Planning Committees

Bill Bury, Eric Challeen, Jeremy Chamberlain, Nicole Chinadle, Jeremy Fritz, Erik Garborg, Dan (Scott) Grieshaber, Jared Harris, Terry Hodgson, Forrest Huisman, Amy Hylfield, Kira Kountz, Jim McCray, Matthew McKamey, and Sean Sandborgh.

MSU Student Interns on the EPICenter Project

Summer 1998

Jim McCray

Fall 1998

Ginger Dunlap, Brad Schlepp

Spring 1999

John Bender, Janna Betty, Nicole Chinadle, Matt McKamey, Sarah Morgan, Kere Sheppard, Chen Fong Soo, Mark Stierwalt, and Betsy White

Summer 1999

Kiritan Williams

Fall 1999

Kerri Johnson and Christina Overton

Spring 2000

Kristin Hagadone, Brian Higginson, Christopher Keller, Lynn Kelting-Gibson, Paul Kraft, Vickie Kraft, Deborah Smith

Summer 2000

John Lewis and Christopher Nickle

MSU lobbyists with Montana Legislature, on campus, and in the community

President

Michael Malone

Vice President of Administration and Finance

Robert Specter

Vice President of Research
Robert Swenson

Students: Brad Bakemeyer, Annie Gates, Sara Converse, Justin Elliott, Jeremy Fritz, Melissa Galano, Eric Gustafson, Jared Harris, Jim McGrav and Matt McKamey

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MSU Safety and Risk Management Division
Jeff Shada, Scott Rogers, Verna Bagley

MSU Students in Anders Larsson's Civil Engineering CE457 Class 1999-2000

MSU Students in Tom Wood's Architecture Senior Design Class, 1997-1998

MSU Students in Bill Neff's Film and Television classes, 1994-1998

MSU Graduate Students in Construction Engineering of Greg Brice and Cory Fraser, Fall 1999

MSU Office of Facilities Services
Robert Lashaway, Cecilia Vaniman, Jeff Davis, Ed Sondeno, Pam Lingenteller, Loras O'Toole

MSU President Michael Malone, who left this earth in December 1999.

MSU (Interim) President Terry Roark, 2000

MSU President's Executive Council 1993-1995
Provost Mark Emmert, Vice President of Administration and Finance James Isch, Vice President of Research Robert Swenson, Vice Provost for Student Affairs Allen Yarnell

MSU President's Executive Council 1995-1998
Senior Vice President and Provost Joseph Chapman, Vice President of Administration and Finance Robert Specter, Vice President of Research Robert Swenson, Vice President for Student Affairs Allen Yarnell

MSU President's Executive Council 1998-2000
Interim Provost David Dooley, Vice President of Research Tom McCoy, Interim Vice President of Administration and Finance Thomas Stump, Vice President for Student Affairs Allen Yarnell

MSU Faculty and Staff who participated and supported the project
Jerry Bancroft, John Brittingham, Gordon Brittan, Patricia Butterfield, David Caditz, Mary Cloninger, Norm Eggert, Sharon Eversman, Joe Feddock, David Gibson, Thomas Gibson, Paul Grieco, Gwen Jacobs, Dallas Johnson, Ann Keenan, Anders Larsson, Martin Lawrence, Tom Livinghouse, Pat Lynes-Hayes, Becky Mahurin, Robert Marley, Cyd McClure, Bill Neff, Kim Obbink, Regan Peuse, Dick Pohl, Bill Preiss, James Robinson-Cox, Robert Rydell, Leslie Schmidt, Gary Strobel, Leslie Taylor, Annette Trinity-Stevens, David Todd, Giri Venkataramanan, Tad Weaver.

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Jim Masker, Hans Haumberger

National Renewable Energy Laboratory, Golden, CO

Lou Abernathy, Doug Balcomb

Northwest Environmental Business Council, Helena, MT

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Palmquist and Palmquist, Bozeman, MT

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Rocky Mountain Institute, Old Snowmass, CO

Amory Lovins, Hunter Lovins, William Browning

State of Montana Architecture and Engineering Division

Tom O'Connell, Russ Katherman, Dal Smilie, Ron Wilkinson, Kathy Willis

State of Montana Department of Environmental Quality

Lou Moore, Tom Livers, Georgia Brensdal, Marla Larson

State of Montana Governor's Office

Julie Lapeyre, Linda Reid

State of Montana Secretary of State

Mike Cooney

Turner Construction Co., Seattle, WA

U.S. Department of Energy

Mark Ginsberg, Deputy Assistant Secretary, Ernie Moniz, Under Secretary

U.S. Green Building Council, Washington, D.C.

Yellowstone National Park, Mammoth, WY

Chief of Park Maintenance Tim Hudson, Chief

Landscape Architect Eleanor Williams

and finally, the two groups who gave the most support

National Institute of Standards and Technology (NIST), Gaithersburg, MD

Dr. Jim Hill, for overseeing the entire project

Drs. Hunter Fanney and Andy Persily, for scientific evaluation and encouragement

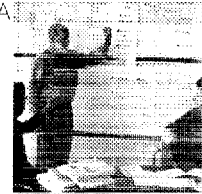
and

Spouses and friends who listened more than they wanted and encouraged the team to keep "heading into the storm."

4.2

EPICenter TIMELINE

Nancy Harris + Kathy Achelpohl AIA




8/1993 Submission of Phase I Planning Grant Proposal, "Development of "Green Building" Guidelines for an Educational Outreach Program, Technology Transfer & PERTT Building at Montana State University," to NIST.

10/1993 Berkebile Nelson Immenschuh McDowell Architects (Kansas City, Missouri) selected in a national competition to assist MSU with Phase I-Concept Development.

2/1994 NIST awards \$200,000 for the development of MSU's Phase I Proposal. Project Team proposes to expand scope of Phase I to include studies in resource conservation, human health and productivity, and impacts on economic vitality in the region.

6/1994 NIST reviews Phase I concept and approves additional \$200,000 to expand Phase I. BNIM and MSU assemble a National Team with local participants that includes architects, engineers, historians, building ecologists, materials specialists, artists and others.

8/1994  MSU Green Building Programming Workshop in Bozeman, Montana develops project goals. Concept suggests a two phase (53,400 to 108,370 square foot) building with laboratories, demonstration areas, "incubator" space for spin-off businesses, offices, classrooms, conference facilities and guest quarters for visiting scientists or corporate partners.

11/1994 MSU Green Building Design Charrette 1 held in Bozeman. Working groups include Regional/Community Team, Site/Neighborhood Team, Human Factors Team, and the Building Design Team-Physical Factors Group.

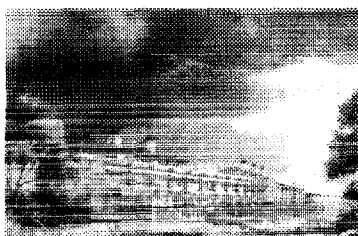
1/1995 to 9/1995 Development of new design tools, building systems and mapping resources in the region (300-mile radius) for MSU Green Building/National ReSource Center (NRC) Concept design.

2/16/1995 to 2/18/1995 Second Green Building Charrette held in Bozeman.

10/1995 BNIM Architects and MSU submit Phase I technical report for the "National ReSource Center" to NIST. Technologies/methodologies highlighted include; Solar Aquatic Wastewater treatment, Utilization of ResourceMapping to create new building materials from Montana Waste Streams, Passive Photon Collector Lighting Devices, Hybrid Photovoltaic-thermal



EPICenter Timeline
MSU + BNIM



Collector, Stirling Engine, Decision Support System for Life Cycle Analysis, Natural Conditioning Systems, Dynamic Computer Modeling Tools, and Methodology to Collect and Evaluate Feedback on Human Factors.

- 1/1996 "Plus Ultra" concept introduced and adopted for the project.
- spring/summer 1996 Representatives of the ASMSU Senate and MSU Administration develop initial proposal for a new classroom/laboratory building on campus. VP for Research, Robert Swenson, proposes to US Senator Conrad Burns for Congressional support. Discussions begin combining classroom/lab project with green building project.
- 7/1996 Board of Regents Meeting—Preliminary approval given to MSU to assess student fee for the new classroom/lab building. Leadership provided by James McCray, 1996-97 ASMSU President.
- 10/1996 Congress appropriates \$1.2 million for development of the National ReSource Center.
- mid 10/1996 Public relations campaign for student support of new building and proposed fee increase begins.
- 10/1996 Student vote on increased fees for the new building—66 percent in favor with 1,300 students voting (11 percent turnout—highest ever at MSU).
- 11/12/1996 MSU President Malone assembles conceptual planning committee, comprised of 50 percent students/50 percent faculty and staff, to consider potential program, site and design concepts for the new building envisioned to be an integrated learning center. Kath Williams appointed Project Chief and co-Chair of Planning Committee with Robert Lashaway, Director of MSU Facilities Services.
- 11/1996 Board of Regents Meeting—Final approval with authorization of up to \$26 million for MSU's new academic building.
- 11/12/1995-12/12/1995 MSU forums to gain input from faculty, students and staff for building use and design. Place Architecture, Bozeman, leads the design team that includes BNIM Architects and national green design consultants.
- 5/1997 1997 Legislative Session begins. University presentations to discuss new building with individual legislators.
- 1/13/1997 Conceptual planning committee sends Proposal for Green Classroom/Lab building to MSU's President's Executive Council for approval.
- 2/1997 Classroom/lab building presentations to the Legislature's Long Range Building Program Committee. MSU President Malone and ASMSU President James McCray present. Senator Tom



Beck carries amendment to amend academic building into LRBP package, as it had not previously been included due to time restrictions.



3/1997 Classroom/lab building contained in Montana House Bill (HB5) sent to House Appropriations Committee. HB5 passes out of Appropriations Committee and goes to House Floor. New building specifically cut out of HB5 on House Floor during the 2nd reading, along with University of Montana Alumni building authorization.



4/1997 Classroom/lab building reintroduced in Montana Senate Finance and Claims Committee. Senator Tom Beck carries amendment. President Malone and ASMSU President McCray present. Senate Finance and Claims Committee amends the bill to authorize \$19 million and one-half operations and maintenance costs. HB5 sent to Senate Floor with amendments. HB5 passes Senate Floor. HB5 rejected by House Floor. HB5 sent to Conference Committee. State funding for Operations and Maintenance cut out of new building project during Conference Committee. MSU emerges from 1997 Legislative Session with \$19 million in authorization for new academic building but no state funding to cover operations and maintenance costs.



5/1997 MSU retains Place Architecture as architects of record and to lead the conventional building contract, and BNIM Architects, under NIST contract, to lead the green building technologies design and development components for the project. Preliminary fundraising committee is formed to raise \$4 million.



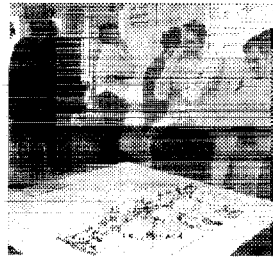
6/1997 Submission of proposal to NIST. "Development of 'National ReSource Center' at Montana State University as Phase II of a National 'Green Building' Demonstration Project." Mission statement and goals defined. Gottfried Technologies presents Industry Partner Program to MSU planning committee. HERA retained as laboratory programming consultant. Kath Williams and Bob Berkebile present project on Capitol Hill requesting \$6 million in support.

6/23/1997 - 6/24/1997 Initial Planning Charrette for MSU's new integrated learning center with project stakeholders to review program needs, potential building sites, and to define project goals. Fundraising goal of \$50 million established by Planning Committee and Design Team.

7/1997 Gottfried Technologies retained for development of Industry Partners Program. Interviews with probable building occupants to define space needs. Students identify priority goal of creating space for interaction between all students, the researchers and NRC.

7/29/1997 Site Selection Charrette. Cleveland site recommended on the condition that the entire Chemistry/Biochemistry Department be moved to the new facility. Building size grows to approxi-





mately 250,000 square feet. University Facilities Planning and Utilization Board endorses Cleveland site. "The money has no color," is adopted as guiding principle (the project is deemed a whole project and every user group contributes to total project costs).

8/1997 Larger project goals developed and guidelines redefined. Site recommendation to MSU President's Executive Council (PEC). Outline "Concept Program" for potential contributors. Building Planning Committee recommends the project be called the "MSU EPICenter" in recognition of the impact they envision for scientific discovery, teaching innovation and sustainable building design. MSU PEC approves Cleveland site.

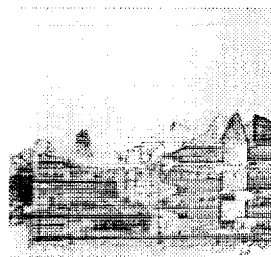
summer/fall 1997 Research continues to define the technologies and methodologies for inclusion in the NIST sponsored research. Technologies considered include the living machine, passive cooling, passive photon collector, fuel cells, lab fume hood innovations, air scrubbing devices, integrated hybrid solar collector and new building materials.

9/1997 Big Sky Institute workshop on innovations in building design for science instruction helps define spatial implications of "integrated learning." NIST approves MSU plan for \$1.2 million for technology research and development for a green building demonstration project.

10/1997 US Congress appropriates \$5 million for project research and development program. Design Charrette to discover breakthrough ideas that illustrate how the EPICenter project will achieve "Plus Ultra" goals of defining new state of the art for science/research facilities and sustainable building design.

11/1997 President Clinton exercises line-item veto on \$5 million appropriation in US Department of Commerce (NIST) budget.

1/5/1998-1/8/1998



Design Charrette to review the status of programming, develop site and image studies, discuss lab precedents and new hybrids, present Plus Ultra systems diagrams and define zero polluting emissions goals for air and water. Footprint of building reduced to 200,000 square feet based on cost projections.

1/1998 MSU delegation meets on Capitol Hill to fight veto. USGBC board members join Kath Williams at White House to support reinstatement of \$5 million.

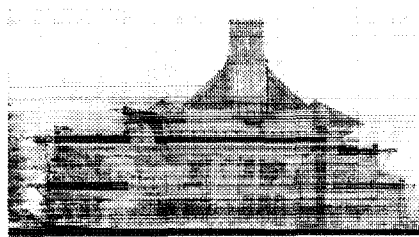
2/14/1998-2/22/1998 Design team meets in KC to review and integrate sustainable design strategies and Plus Ultra technologies into the EPICenter concept building design.

TECHNOLOGY RESEARCH

2/1998 Montana Legislature grants exemption to low-bid process on all "green" products and systems. Contractor is excluded. Team members visit "Living Machine" in Burlington, Vermont to review biological wastewater treatment issues.

3/1998 Faculty Council drafts a resolution to 1) shut down the project or 2) revert back to the \$19 million building. No action taken by President's Executive Council (PEC). Industry Partners Program is advertised in newspapers statewide. Kath Williams and US Green Building Council board members meet with US Office of Budget and Management to protest line-item veto.

5/1998 Design team presents conceptual design for the MSU EPICenter to the President's Executive Council. Design includes biological wastewater treatment, natural ventilation towers, air scrubbers, hydrogen fuel cells, hybrid PV, and daylighting systems including the photon collector. Meeting with potential Industry Partners is held in Bozeman. Evaluation of Hamilton Hall for recycling opportunities during demolition is completed by Place Architecture.



6/1998 President's Executive Council extends \$50 million fund raising deadline to December 15, 1998. Proposal to PEC for a Demonstration Site for EPICenter Design Features in the USDA building. PEC declines to support renovations to facilitate mockups. US Supreme Court overturns line-item veto power of the Presidency (\$5 million).

7/1998 NIST approves 1-year extension for Phase II (\$1.2 million). PEC requests alternate plan for a smaller building be developed in the event additional funding is not secured by December.

8/1998 Industry Partners strategy meeting held in San Francisco. PEC approves fund-raising period ending June 1999.

9/1998 NIST approves MSU proposal for the expanded (\$5 million) NIST R&D program. Much debate about meeting user and programmatic needs in the face of administrative and budgetary constraints at MSU; multiple alternative scenarios proposed. Planning Committee requests that PEC set December 15th deadline for the exploration of the phasing of the project.

10/1998 Planning Committee and Design Team redefine project goals. Planning Committee votes to develop a \$19 million building and a plan for scaling up the project. Notice to participants that all planning meetings are open to the public.

10/13/1998-10/14/1998 "Beyond 2000 - Technology and Integration, Changing the Way We Teach, Learn and Build" is held on MSU campus. Guest lecturers included Robert Morris, James Hawkins, EPICenter team members from Supersymmetry, Solar Design Associates, the Center for Maximum Potential Building Systems (CMPBS), University of Florida, Lawrence Berkeley National Laboratory, Burns Telecommunication Center, BNIM Architects and SPACE. Team meeting with Fisher Hamilton and Lawrence Berkeley National Laboratory to discuss fume hood innovations for the project.

10/13/1998-10/15/1998 Industry Partners meeting with potential partners on campus. The design team presents the EPICenter Concept.

12/1998 Planning Committee unanimously passes resolution to construct a smaller "pilot" building and continue efforts to fund concept building. The prototype building will test some of the concepts developed for the larger EPICenter and will generate enthusiasm for the larger building project. Turner Construction provides evaluation for remodeling and/or building an addition to Gaines Hall.

1/1999 MSU President and PEC reorganize project into NIST R&D component and conventional construction project with a \$10 million budget. Kath Williams continues as Executive Director of the NIST component, and David Dooley, Chair of the Department of Chemistry, as Chair of a new building committee. The EPICenter Planning Committee is dissolved.

Fisher Hamilton chosen as first industry partner in R&D program.

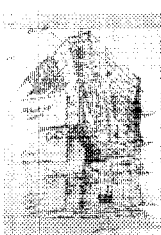
PILOT PROJECT

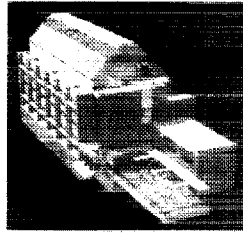
2/1999 The construction project is divided into three components - the renovation of an existing building to house the Center for Computational Biology (\$750,000), the renovation of two chemistry teaching labs in Gaines Hall (\$320,000) and the EPICenter Pilot building (\$7,317,000). Fifth Industry Partners meeting with potential partners from Montana is held. Team members travel to CA to view technology demonstrations at LBNL (fume hood) and McClellan Airforce base (CHA - air scrubbing technology).

3/1999 MSU recommends subcontracts to NIST totaling \$3 million for industry Partners R&D projects, specialty consultants and MSU faculty researchers.

3/1999-4/1999 Programming Phase for the EPICenter Pilot Project.

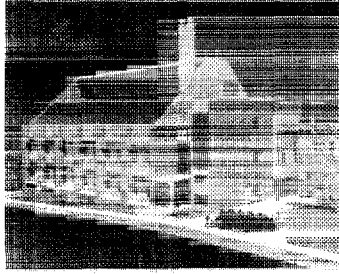
4/1999 Schematic design Charrette for the EPICenter Pilot building in Bozeman. A 30,000 square foot addition on the south side of Gaines Hall (Chemistry) will be developed. Team members meet with AvistaLabs in Spokane, Washington, to discuss fuel cell partnership.





- 5/1999** NIST team is organized into four groups—Performance Team (includes Air and Exhaust), Materials Team, Water and Waste Team and Power Team. Air and Exhaust Team members meet with Fisher Hamilton and CHA in Wisconsin. MSU assembles a multidisciplinary faculty team to study human health and productivity issues related to occupants of green buildings.
- 6/1999** Schematic Design for the Pilot Building is submitted to MSU. Place Architecture withdraws from project, and BNIM becomes the Architect of Record for the Pilot Building. CTA Architects and Engineers (Billings, MT) expand their role on the team as Project Architects for the renovations. NIST Funds are approved for R&D projects for Industry Partners and MSU participants: Lawrence Berkeley National Labs receives funding to test low-flow fume hood, daylighting and glazing, materials assessment, and technical support. MSU Civil Engineering Department receives an award to evaluate waste reduction opportunities in the construction process. MSU Extension Service receives funding to develop concept for National Resource Center. Solar Design Associates receives award to further their development of the integrated, hybrid photovoltaic thermal solar collector. MSU Chemistry Department awarded funding to develop Inquiry Centered Learning computer software. MSU Center for Biofilm Engineering funded to develop a wastewater treatment prototype. MSU School of Architecture funded to study daylighting. Water and Waste Team meets in Bozeman to discuss progress on wastewater treatment including EM technology.
- 7/1999** Materials team meets in KC to discuss material selection for the major building components in the Pilot Building and in Bozeman to discuss opportunities to incorporate reinforced cast earth into the Pilot building. Fisher Hamilton/ISEC installs prototype fume hood in Gaines Hall research laboratory.
- 9/1999** NIST approves 1-year extension for Phase II (\$5 million). Italiano and Partners awarded funding for development of Sustainable Products Training. MSU Plant and Soil Sciences awarded funding to conduct research on bioremediation. MSU-Northern receives funding to pursue R&D in strawbale construction, emissions testing, and hydrology. Performance team meeting in KC to evaluate mechanical systems and daylighting/lighting design.
- 10/1999** Air and Exhaust subgroup of the Performance team meets in Bozeman to discuss fume hood strategies, commissioning, and CHA's progress on air scrubbing. The integrated, hybrid solar collector is put on hold due to activity in Congress that cut DOE's renewable energy budget. EPA does not approve funding for the Pilot building wastewater treatment facility. Industry Partners (Fisher Hamilton/ISEC, Lightolier, Owens Corning, Forbo, AFM Paint, Collins and Aikman, Miliken and Shaw) are asked to submit proposals to provide products for the Lewis Hall lab renovation.



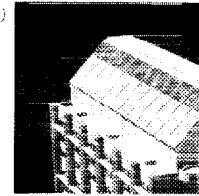


- 11/1999 Performance Team meeting in KC. Topics include daylighting/lighting, mechanical systems and passive cooling strategies.
- 12/1999 Renovation of Lewis Hall for the Center for Computational Biology (CCB) begins. Industry Partners (Fisher Hamilton/ISEC, Lightolier, Forbo, AFM Paint) are asked to submit proposals to provide products for the Gaines Hall teaching lab renovation.
- 1/2000 Design development documents for the Pilot building are approved by MSU.
- 2/2000 Pilot building design team members meet in Bozeman for coordination and user group meetings. MSU pursues a \$2 million NIH grant to expand the scope of the Pilot building project. MSU administration decides to push the bid date for the Pilot building to the first quarter of 2001.
- 4/2000 Commissioning subgroup of the Performance Team meets in Bozeman with FICO (Commissioning Agent for the Pilot Building) and representatives from State of Montana A&E. Power Team meeting in KC to discuss development of integrated, hybrid solar thermal collector. Materials Team meeting in KC.
- 6/2000 The renovation of four chemistry teaching labs in Gaines Hall begins. The renovation of Lewis Hall for the CCB is completed. MSU administration directs the design team to make Pilot building design changes requested by the researchers. Changes include making a secured lab suite area on the research floors to limit general student access.
- 6/20/2000 Meeting with LBNL and MSU Safety and Risk Management to discuss prototype installations in MSU's Advanced Technology Park (ATP). MSU Safety and Risk Management Division agrees to host site for prototype demonstrations.
- 7/2000 BNIM submits 95 percent Construction Documents for the Pilot building to MSU for their final review. Commissioning Subgroup of the Performance team meets in KC with Johnson and Phoenix Controls to discuss design of Pilot building monitoring system.
- 8/2000 Installation of prototypes begin in Advanced Technology Park.
- 9/11/2000-9/12/2000 NIST review of prototypes at MSU's Advanced Technology Park. Prototype presentations made by Solar Design Associates, Fisher Hamilton, LBNL, CHA Corp. and Headwaters Composites.
- 9/30/2000 Term for NIST R&D funding ends. Final NIST report submitted. The EPICenter Office is closed. Project research materials archived at MSU College of Arts and Architecture and BNIM Architects, Kansas City, Missouri.

4.3

BUDGET NARRATIVE

Kath Williams Ed.D



Montana State University competed nationally for the first National Institute of Standards and Technology (NIST) grant in 1993. Upon receipt of \$200,000 for design of what was named the National ReSource Center, MSU selected an international team of architects, engineers and specialty consultants. The results of their initial energy efficiency strategies, concepts and designs were presented to NIST, which chose to expand the grant by another \$200,000 so that the design could be enhanced to demonstrate resource conservation.

In 1996, Senator Conrad Burns (R-MT) introduced US Congressional legislation that would support the project. Expenditures of the funds appropriated by the US Congress to the National Institute of Standards and Technology emphasized the research and development of "green building" technologies and the incorporation of the prototypes into a holistic, "living building" design. Two appropriations were approved by Congress—the first in FY97 budget for \$1.2 million and the second for \$5 million in the FY98. The later was subjected to President Clinton's line-item veto and was not reinstated until FY99 when the US Supreme Court overruled the veto power of the administration.

The following charts show the allocation of \$5,939,300 funding to Montana State University, after the NIST Facilities and Administration charge was deducted. Forty percent of the available funds were used in direct subcontracts to industry for research and development projects. This totaled approximately \$2.4 million and resulted in five "green building" prototypes, four of which have been installed at Montana State University's Safety and Risk Management laboratory. Other research projects resulted in a Portland cement alternative from the Montana waste streams, detailed plans for an on-site biological wastewater treatment facility, protocol and research methodology development for the study of human health and productivity, construction waste management system specifications, software to reduce the use of chemicals in laboratories, daylighting studies, a strategic plan for a National ReSource Center, support for emissions testing, straw bale construction code work, and a rainwater harvesting pilot system. Two projects involved low-grade lumber, including stress testing standing trees to prevent wasteful harvesting and the development of laminated lumber for structural beams.

Approximately one-third of the funds were used for design services that enabled the development of a holistic building design to enhance the economic and environmental vitality in the region and create prototypes and other "green building" technologies for industry. This was accomplished through the leadership of the architectural firm, BNIM Architects of Kansas City, who have been with the project since its inception in 1993. They worked together with a diverse team of international experts. An essential component of collaborative design was the development and inclusion of industry through a partners program. Over 100 industries expressed intent to partner and over 30 visited MSU's campus to participate in design and educational outreach programs. Design services also included the work of scientists from Battelle Pacific Northwest Laboratories in the area of human health and productivity so the EPICenter project could advance the science of human factors.

VALUES



Budget Narrative
Kath Williams

Facilities and administration (formerly known as Indirect Cost recovery-IDCs) were collected by Montana State University (over \$700,000) in order to cover the costs of housing and supporting the project. This accounted for less than 15% of the funds allocated.

An additional 5% of the funds (approximately \$300,000) were spent on salaries and benefits for student interns on the project, EPICenter office staff, and an MSU/NIST subcontract manager who did not participate as a team member but reported directly to the MSU Vice President of Research. The director of the project was paid by MSU, using IDCs, until the last 18 months of the project when her salary was transferred entirely to the project account.

Less than 1% of the funds (less than \$50,000) were spent on four years of travel for the project director to present at conferences and/or meet with industry partners, for project participants to attend related conferences and educational seminars, and for in-state travel by project staff.

Miscellaneous expenses, including supplies, communications, office equipment and meeting rentals, totaled less than \$40,000 for the four-year fiscal period.

With the adoption of the "Plus Ultra" approach, the design team accelerated advancements in sustainable design using some of the nation's best experts. These included independent consultants, industry and university researchers, national laboratory experts, and architectural/engineering firms. Combining the funds spent for specialty consultants (under the Design Services category) and the funds spent for direct research and development projects (the entire 40%), work was accomplished in the following categories:

Pollution prevention, including prototype air scrubbing system and emissions testing protocol	18% or slightly over \$500,000
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Fume hood advances	20% or approximately \$550,000
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Water and waste, including biological wastewater treatment facility development rainwater harvesting, and construction waste management	12% or close to \$350,000
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Power, including phototherm prototype and PEM fuel cell testing	10% or approximately \$280,000
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Concrete alternatives, including Portland cement substitute, cast earth technologies, and structural testing	9% or approximately \$260,000
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Enhanced health and human development	8% or slightly over \$230,000
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Sustainable systems design	7% or slightly less than \$200,000
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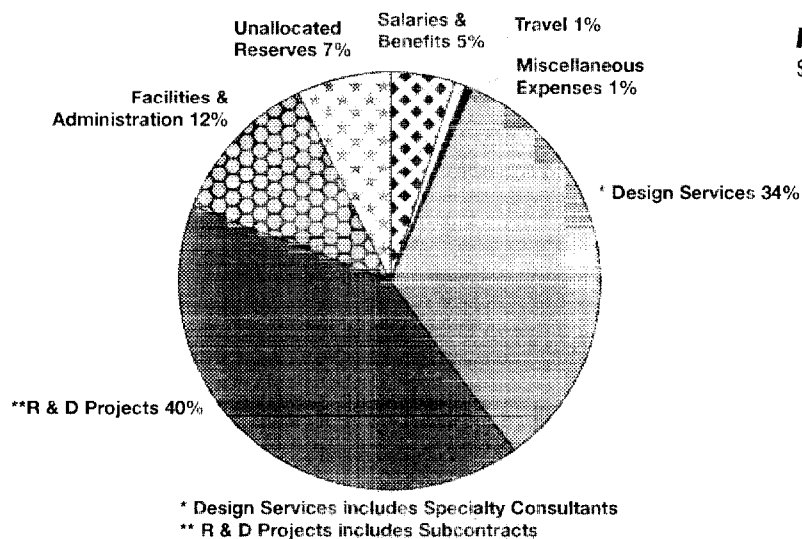
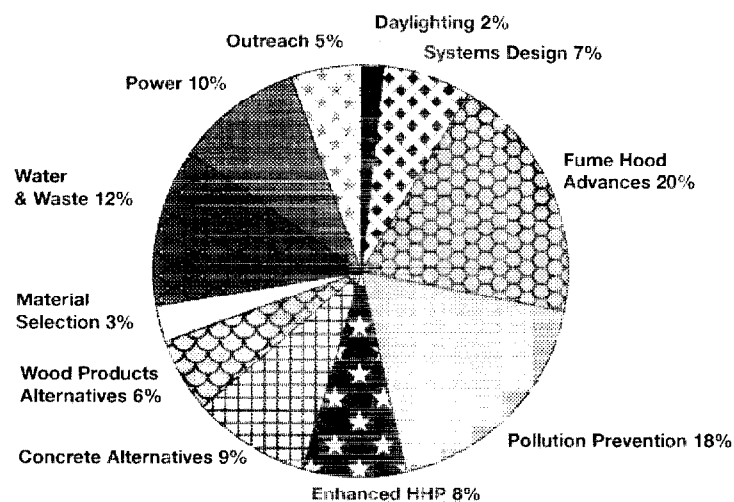
Wood product alternatives	6% or approximately \$165,000
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Outreach, including development of NRC, sustainable products manual, and software for Chemistry classroom use	5% or slightly over \$150,000
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Material selection matrix development	3% or approximately \$85,000
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Daylighting strategy development	2% or slightly less than \$50,000
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The grant period ends September 30, 2000, with approximately \$425,000 in unused funds. NIST offered Montana State University a third, no cost extension to continue with the monitoring and testing of the prototypes installed in the Advanced Technology Park.



4.4

LIST OF TECHNICAL REPORTS

included on the companion CD-ROM:

PERFORMANCE TEAM

Daylighting and Lighting

Daylighting Computer Modeling

By Thomas R. Wood, AIA, IES

Professor of Architecture Montana State University, Bozeman

Daylighting for the MSU EPICenter Pilot Building

By Monica Rodriguez and Jason McLennan, BNIM Architects

Electric Lighting Design for the EPICenter Pilot Building

By Nancy Clanton, PE, Clanton & Associates

Systems Design

Energy-Efficient Integrated Mechanical System

By Shawn Murray, PE, CTA Architects Engineers

MOE2 Simulation of MSU EPICenter Labs

By Peter Rumsey, PE, Supersymmetry

Flow Visualization Methods for Passive Cooling Design

By Monica Rodriguez and Jason McLennan, BNIM Architects

Passive Cooling and Ventilation of the EPICenter Pilot Building Atrium

By Baruch Givoni, Ph.D, UCLA

Plus Ultra Commissioning

By Ronald L. Perkins, Supersymmetry USA

Laboratory Hood Ventilation of the EPICenter Pilot Building

By Gerhard W. Knutson, Ph.D, CIE, Knutson Ventilation Consulting, Inc.

Building Ecology: Indoor Air Quality and Climate in the Energy Efficient EPICenter Pilot Building

By Hal Levin, Building Ecology Research Group

Fume Hood Advances

Current State of the Art in Fume Hood Technologies

By Janet Baum, AIA, Health Education and Research Associates

Laboratory Fume Hood Innovations and Air Treatment Technologies

By Rick Johnson, Fisher Hamilton LLC

Improving Laboratory Fume Hood Performance

By Dale Sartor and Geoffrey Bell, Lawrence Berkeley National Laboratory

Zero-Polluting Emissions/Pollution Prevention

Microwave Air Purification System for Treatment of Fume Hood Exhaust

By Chang Yul Cha and Charlie Carlisle, CHA Corporation

Monitoring and Analysis of Emissions Through the Use of Portable Emission Analysis Equipment

By Wayne Boysun, Montana State University - Northern

Enhanced Human Health and Productivity

The Green Building Hypothesis

By Judith Heerwagen, Ph.D

Green Games Building Interface Research Team

By Clarann Weinert, SC, Ph.D, RN, FAAN, and Deborah C. Haynes, Ph.D, Montana State University - Bozeman



LEAN FACTORS

MATERIALS TEAM

Development of New/Alternate Material

Structural Testing of High Percentages of Fly Ash in Concrete

By Steve Brackman, Beaudette Engineering

New Building Materials with Advantageous Properties Incorporating High Recycled/Agricultural Waste Content

By Charles W. Hedley, Headwaters Composites, Inc.

Development of Alternate Building Materials for the EPICenter Pilot Project: Cast Earth and Fly Ash Concrete

By Jerry Stephens, Doug Cross, and Matt Anderson, Montana State University - Bozeman and Michael Frerking, Living Systems Architecture

Glued Laminated Beams from Low Grade Lumber

By Ernest Schmidt, Chris Wallace and Rob Ericson, Wyoming Sawmills, Inc.

Straw Construction Technology

By James Clinton, MSCE, PE, Montana State University-Northern Industrial and Engineering Technology

Stress-Wave Analysis of Standing Trees To Improve Recovery of High-Stiffness Wood for Engineered Wood Products

By Thomas M. Gorman, Ph.D., PE, and Francis G. Wagner, Ph.D., University of Idaho

Material Selection

GreenBalance: CO₂ Balancing of Superstructure and Exterior Closure Building Group Elements

By Richard MacMath and Pliny Fisk III, Center for Maximum Potential Building Systems

Systematic/Holistic Application of Environmental Life Cycle Assessment to Building Material Selection: Input/Output-Based Prioritization Analysis and Process-Level Structural System Analysis with Athena

By Gregory A. Norris, Ph.D., Sylvatica

Updated Baseline Analysis of the Upstream Environmental Burdens of the MSU EPICenter Pilot Building

By Gregory A. Norris, Ph.D., Sylvatica

Development of Linkage Between AIA MASTERSPEC and BEA Categorization Systems: with Application to the MSU EPICenter Pilot Building

By Gregory A. Norris, Ph.D., Sylvatica

Material Selection and Specification for the MSU EPICenter Pilot Building

By Phaedra Svec, AIA, BNIM Architects

Industry Partners Program

By Kath Williams, Ed.D., Montana State University - Bozeman

Building Envelope Design

Moisture and Thermal Issues in the MSU EPICenter Pilot Building Envelope

By Greg Sheldon, AIA, BNIM Architects

WATER AND WASTE TEAM

Waste and Water

An Integrated Wastewater Management System for the EPICenter Building

By Anne K. Camper, Warren L. Jones, and Otto R. Stein, Montana State University - Bozeman

EPICenter Bio- and Phytoremediation Project: Integrating Undergraduate Research at MSU-Bozeman

By Ricky M. Bates and William E. Dyer, Montana State University - Bozeman

Water Conservation

By M. Gregg Hester, Montana State University - Northern

Waste Reduction Specification

By Douglas R. Jost, Montana State University - Bozeman

POWER TEAM

Solar Power

Integrated Hybrid Photovoltaic Thermal Collectors

By Steven Strong, Solar Design Associates

OUTREACH TEAM

Outreach and Education Opportunities

Sustainable Products Training

By Mike Italiano, Italiano and Partners, P.C.

National ReSource Center For Sustainable Technologies

By Michael P. Vogel, Montana State University - Bozeman

Integrating Research into Undergraduate Education

By John R. Amend, Montana State University - Bozeman

EDUCATION

The Technical Reports are available on the CD-ROM included at the back of this report.



List of Technical Reports

